Multidiszciplináris tudományok, 13. kötet. (2023) 1 sz. pp. 372-380 **https://doi.org/10.35925/j.multi.2023.1.27**

DESCRIPTION OF THE MANAGEMENT OF A MAJOR HAZARD EVENT IN A HIGH PRIORITY INSTALLATION

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Abstract
Industrial accidents and accidents caused by natural disasters in factories, plants and power stations are the most dangerous and pose the greatest risk. As a result of social and economic development, more and more energy carriers, raw materials, semi-finished and finished products are produced and marketed, which may pose a risk to the environment and the public. In the course of our work, we have studied a facility or plant that is a high priority, including one where ammonia is present as part of the technology in quantities of over 1,000 kg. We examined the different types of accidental events that can occur in this type of plant and the need and importance of the measures taken to deal with these events and their purpose. Our aim is to identify weaknesses, propose solutions and develop alternatives for improvement. To ensure the highest standards of safety and protection of workers at work and to emphasise the shared responsibility of senior management and all workers to achieve and maintain an effective safety management system. Through our work, we want to contribute to the improvement, development and safer management of activities in an operational high priority plant.

Keywords: *occupational safety, human safety, major hazardous factory, disaster management*

1. Introduction

The growth in the volume of industrial production has led to the development of public control of the activity from the point of view of law and order and technical safety. The development of these controls followed industrial disasters with significant human and environmental consequences, both in Hungary and abroad.

In the European Union, the Seveso Directive was developed to establish a single control system for the prevention and mitigation of the effects of dangerous industrial accidents, and has been amended several times in the wake of subsequent industrial disasters. Then, with the introduction of the CLP Regulation on classification, labelling and packaging of substances, including mixtures (hereinafter

CLP) on 01 June 2015, it became necessary to adapt the Directive to this system. It was therefore no longer sufficient to amend the existing Seveso II Directive again, but a new Seveso III Directive was drafted and adopted, which has been in force since then. One of the main elements of this is the alignment of the list of dangerous substances and the hazard categories with the CLP system, which may lead to changes in the classification of dangerous establishments. Its transposition into the Hungarian legal system is reflected in Act CXXVIII of 2011 on disaster management and the amendment of certain related legislation (hereinafter: Cat. tv.), and in the implementing Decree of the Government of Hungary 219/2011. (X. 20.) on the protection against major accidents involving dangerous substances. The SEVESO III Directive provides guidelines for the preparation of risk analyses, the risk reduction measures that can be derived from them and the necessary protective measures to be taken in the case of plants processing and manufacturing hazardous substances. Technical safety measures to prevent the escape of hazardous substances, equipment to ensure that plant process parameters are kept at a good level, instrumentation to indicate and prevent critical increases in parameters and detection systems to detect the escape of hazardous substances play an important role in this (Koch, 2014).

Based on the Government Decree 219/2011. (X. 20.) on the protection against major accidents involving dangerous substances, we distinguish between plants with lower threshold hazardous substances, plants with upper threshold hazardous substances and facilities to be treated as priority. Priority hazardous installations include, among others, installations where chlorine or ammonia is present in quantities of at least 1,000 kg.

Act XCIII of 1993 on Occupational Safety and Health stipulates that “The personal, material and organisational conditions of safe and healthy work shall be provided in accordance with the interests of protecting the health and working ability of workers at work and of humanising working conditions, thus preventing accidents at work and occupational diseases, and the duties, rights and obligations of the country, employers and workers”. The practical implementation of the legislation is facilitated by ministerial and government decrees and laws. These are supplemented by safety codes and standards for the sector, as well as employers’ internal regulations. Although the use of management system standards is not mandatory in Hungary, organisations operating such certified systems are required to demonstrate that they operate in accordance with them. Compliance with the standards relating to technical design and technical safety is already required by law. Every workplace is a source of some kind of hazard. Hazards include work equipment, machinery, vehicles, slippery surfaces, the temperature of certain objects, differences in level, air quality, noise, light, radiation, and hazards arising from various types of accident or series of events (Bíró, 2014).

2. Description of the hazardous technology operating in the plant

Ammonia is stored on site as a refrigerant in a closed system. Its operations are carried out in the refrigeration plant and at the ammonia distribution site. The system consists of a number of pressure vessels, condensers, compressors, piping and refrigeration units, which distribute the ammonia present on site.

The filling of the holding vessels, which have different functions and are components of the process system, is incomplete in normal operation. The maximum filling level of the ammonia tanks, which contain the largest quantities of ammonia, may be 50-80%. A higher near-fullness of the tanks is in principle not possible due to the system operating parameters. The quantities of hazardous substances present in the various storage units on the site are as follows:

Table 1. *Amount of ammonia in the refrigeration system at maximum charge*

	Storage location	Volume m^3	Maximum load %	Plant pressure (bar)	The present Maximum quantity (kg)
1.	Liquid waste collector	1,567	80	10	678
2.	Intermediate vessel (–10 ºC)	2,786	50	2	838
3.	Droplet separator (–30 ºC)	1,786	50	0.2	404
4.	Evaporator system(–10 ºC)	697	50	2	222
5.	Evaporator system(–30 ºC)	413	50	0.2	140
6.	Ice accumulation bath (–30 ºC)	1,095	50	0,2	366
7.	Ice accumulation bath (–10 ºC)	1,081	50	2	352
8.	**Total**				**3,000**

Process parameters specific to anhydrous liquid ammonia used on site:

- Concentration: 99.852%,
- Let's go:

Table 2. *Vapour pressure of ammonia as a function of temperature* (BM OKF, 2016)

Temperature [º C]	Vapour pressure [bar]
–20	1,896
0	4.29
+20	8.59
+40	15.62
+50	20.43

Occasionally, it is necessary to top up the cooling system to ensure that the correct level of ammonia is present. This technological process is also a source of risk. The filling of the system is carried out by duly qualified technicians under contract in the presence of a tanker truck equipped for this purpose, with a safety system in compliance with the legislation. This operation is usually carried out twice or three times a year.

3. The risks of the plant under consideration from a hazard perspective

External and internal influences and risk factors were examined from a hazard analysis perspective. For external effects (external causes), natural hazards were detailed, and for internal effects, risks arising from the technological system. In order to prepare for the occurrence of certain natural hazards, it is necessary to know the consequences and adverse effects that can be assumed in hazardous plants (Kátai-Urbán, 2013; Horváth et al., 2018).

In the plant shown, we have listed the possible risk factors and the emergency options that are crucial for rescue operations. The risk assessment areas were divided into three main units, in which a number of risk factors were assessed and evaluated, as shown in the figure below. The risk levels were graded on a scale of low, medium and high and it was shown that the general and work area specific risks were classified as low risk, whereas the technology-activity investigation was more characterised by medium risk levels. That is, a technology system with significant risk operates in a well-designed documentation and work environment.

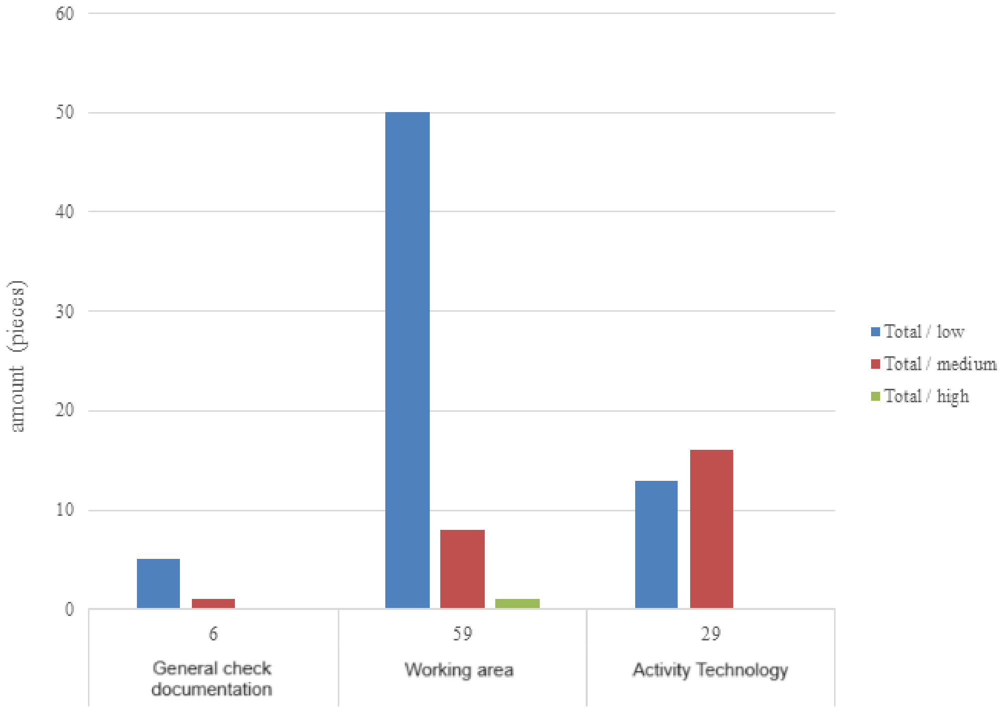

Figure 1. *Number of risk levels identified in three main areas as a function of risk levels*

3.1. Risks from fire

As a risk to be assessed, fire in the plant area is a high priority and cannot be neglected. As mitigation measures, various notification and signalling methods for plant managers and workers have been developed:

Signal, alert, notification:

- It is a citizen's duty to report any fire or imminent threat of fire immediately.
- If the size of the fire detected or the danger of the environment makes it doubtful to extinguish the fire with the available hand extinguishers and other extinguishing agents available on site, or if the fire requires assistance, the professional fire brigade and the person in charge of the police or law enforcement in the area must be notified immediately in order to carry out the local alarm.
- In the event of an emergency, the most important task of the person who detects it is to notify.

How to signal a fire:

- Using a landline or mobile phone to call the general emergency number 112 to report a fire

- The internal alarm. With a shout of “FIRE!”.
- Using the fire alarm system.

Telephone alerts must include the following:

- EXACT LOCATION of the incident/emergency, damage, fire!
- A description of the incident.
- In case of fire: WHAT ARE, how big is the fire (in approx. m²), what is at risk from the fire.
- Are human lives at risk?
- In case of personal injury: number of injured persons, nature of injuries (e.g. severe bleeding, unconsciousness, poisoning, electrocution, immobilisation, etc.).

The importance of telephone numbers during and outside working hours should be stressed.

The signalling and alarm system is ensured, among other things, by the built-in fire alarm system installed on the premises.

In the event of a fire in the ammonia refrigeration circuit, there is reason to expect the containers to rupture or explode. Perhaps the most important aspect of the management of the event is the selection of the right extinguishing agent to disperse or reduce the concentration of the gas cloud that may form. The use of continuous water jets during extinguishing is prohibited as it can lead to the formation of dangerous decomposition products – nitrogen monoxide, nitrogen dioxide. We consider this a risk that must be treated as a priority. Need to be indicated in the technological part of the plant with textual signs.

3.2. Risk of gas leakage

In the event of a hazard, workers must leave the immediate area of the emergency immediately to protect their safety. If the incident could endanger other workers, the area manager may order the evacuation of the building(s), halls and staff at risk (escape). Escape from confined spaces is facilitated by escape route signs in the buildings. When escaping, everyone must retreat to the designated assembly point, unless the assembly point is in the area of the emergency (e.g. hazardous material in the air is blown in the direction of the assembly point), in which case the manager will designate another assembly point.

3.3. Social risk assessment

As the population is the closest to the plant site at 450 m, there was no need for a social risk assessment, so no population was considered.

3.4. Vulnerability assessment of the natural environment due to a chemical accident

Groundwater and geological environment: the operation is unlikely to result in groundwater contamination.

Surface water: during operation, surface water may be affected only in connection with stormwater drainage. The on-site wastewater network is the receptor of stormwater runoff due to the expected low volume.

3.5. Technological risks

The gradual deterioration of hazardous plants over time is a safety factor of major concern both domestically and internationally. Based on the description of the plant under investigation, it can be concluded that a major accident at the site could occur as a result of damage to a point in the ammonia charge system and the release of ammonia. As a result of the assumed damage to the system, the liquid and gaseous ammonia escapes from the system, starts to evaporate rapidly under the influence of the external air pressure and temperature, and a high mass of ammonia gas cloud is generated within a short time.

In the event of an ammonia release, ammonia gas hazards should be considered in virtually all cases (apart from the possibility of a freezing accident to people in the immediate vicinity). The most important properties of ammonia gas are therefore examined below:

Table 3. *Key properties of ammonia* (BM OKF, 2016)

Physical parameter	**Ammonia (NH)$_3$**
normal density at 25 °C [kg/m]^3	0,769
molecular density (g/mol)	17
boiling point at 0 bar [°C]	–3,0
melting point at 0 bar [°C]	–78,0
solubility 20° at C [g/l]	510–531
auto-ignition temperature	651
upper-lower explosive limit	16.0–25.0
vapour pressure at 20 °C [hPa]	8,611

Due to the potential damage that could occur, there is no first-aid facility on the site for rescue operations or the care of injured persons, which can be considered as a risk factor. The designated workers on the site are trained in first aid and the designated first aid post is adequately marked and equipped with a first aid box.

4. Summary of recommendations and conclusions for safe operation

Workers are exposed to a number of health hazards, which are in the interests of both themselves and employers to avoid. The company presented here is doing a lot to comply with the legislation in force, based on our investigations. In line with this, it provides its workers with personal protective equipment and conducts training to ensure a high level of safety. It takes steps to improve working conditions and to increase employee engagement. Based on the data gathered and our personal experience, we concluded that there is always room for improvement in the area of human safety. Workers sometimes do not use the protective equipment provided, do not follow instructions on safety at work and do not report any mistakes that may occur. This can lead to serious accidents, even with the right employer's attitude.

Another problem that occurs in plants that need to be prioritised is maintenance and repairs carried out by subcontractors, especially during annual shutdowns, which occur when the plant is restarted. The quality of the new parts installed and replaced is not always fit for purpose. In addition to the above-mentioned problem, there is the phenomenon of ageing, which is the ageing of the plant. Despite recent improvements, there are still parts of the plant that have been in continuous operation for decades. These are worthy of a complete overhaul, possibly replacement, but this would require a very significant financial investment by the operators, so they prefer to finance ongoing maintenance.

4.1. Organisational tasks

In the context of the organisation of work and work processes, we believe that proper organisation can improve workers' attitudes towards safety at work, thus enabling work to be carried out without accidents.

To achieve this, it may be necessary to:

- Organise training on the responsible use of personal protective equipment, including a practical demonstration of its correct use, with particular emphasis on the gas mask that is being purchased. Involve managers to monitor more closely the availability and use of protective equipment. Emphasis should be placed on the purchase of more comfortable protective equipment, taking into account the views of workers.
- Introduce additional welfare measures to facilitate standing throughout the shift by providing special mats, footwear and protective drinks of appropriate quality. To reduce monotony and the associated inattention, provide opportunities for workplace exercise during working hours and consider the possibility of alternating work activities through work organisation.
- Prioritise the importance of maintenance and error reporting for employees. Encourage managers to carry out more checks. Workers should be made aware that if they are working with faulty machinery, it is dangerous and that they should report the fault immediately. The employer, on the other hand, must ensure that the reported fault is rectified as soon as possible and that the repair is started and carried out in good time by a trained maintenance technician.
- To monitor subcontractors more closely and to organise the documentation of the tasks and sub-activities carried out by them with the same frequency.
- Plant areas containing ammonia refrigeration systems require increased control. The inspection of installed equipment and devices is of great importance, because early detection and correction of faults – replacing faulty equipment – greatly contributes to accident prevention. It is recommended to develop an action plan for the possible replacement of equipment (Zákányiné et al., 2021).

4.2. Personal factors

Strengthening employee engagement among personal factors. One option is to get employees interested in doing quality work by complying with standards. For example, by developing a reward system that motivates employees to work not only regularly but also more efficiently. Another suggestion is to promote a healthy lifestyle.

Monitoring work-life balance so that the worker can spend time with his or her family, not always on the same shift, e.g. not only on night shifts. Rewards for a job well done are a strong motivator, but any action in the interests of the company should be rewarded, especially suggestions and reports on accident prevention.

4.3. Work environment factors

The working environment has a big influence on the quality of the work done there. The aim is to improve this by improving the

- the working temperature. Of the working environment factors, low working temperature in the cold store is the most problematic. It is therefore recommended to provide longer rest periods and warming equipment (protective drinks, shawls) and to optimise shifts. A large difference between the temperature at the workplace and the temperature after leaving the workplace can have a

negative impact on workers' health, as it can lead to colds. And the loss of workers can have a negative impact on the economic situation of the company.
- limiting the amount of screen time for people working at a computer. Workers who spend long periods of time in front of computers experience eye fatigue, reduced vision and attention capacity, and possibly headaches. Stressed senses perform less well than a work pace interrupted by rest periods. In order to maintain workers' attention throughout the shift, it is necessary to give the overstressed nervous system more rest.

5. Summary

Section 54(2) of Act XCIII of 1993 on Occupational Safety and Health – provides that the employer is obliged to assess qualitatively and, if necessary, quantitatively the risks to the health and safety of workers, in particular:
- the technology, work equipment and hazardous substances used,
- the pressures on workers and the design of workplaces.

Risk screening and assessment is a careful review of what harms and endangers those within the scope of work in a workplace and what measures can be taken to reduce the risks to an acceptable level. Also, ITM Decree No. 5/2020. (II. 6.) on the protection of the health and safety of workers exposed to chemical agents specifies that the minimum measures necessary to prevent or reduce the health and safety risks arising from exposure to dangerous substances and dangerous mixtures present at the workplace or used in the work process must be defined.

In the system we studied, we have proposed measures to change organisational, personnel and working environment factors in the assessment of risk factors. In addition to these, the following factors are highlighted in Table 4 as the most significant hazards identified in the ammonia refrigeration circuit.

Table 4. *Major hazards in the operation of an ammonia refrigeration circuit*

Type of hazard	Source of danger	Possible consequences
Mechanical hazards	1. high pressure 2. rough, slippery surface 3. sharp edges 4. high pressure	1. ejection, spillage 2. slip, trip, fall 3. bump, bruise 4. splashing, ejection, burning
Thermal hazards	1. explosion 2. flame 3. low temperature materials	• combustion • combustion • freezing
Noise hazards	1. moving parts	1. ringing in the ears
Hazards of the substance, preparation	1. flammable 2. Gas	1. Fire 2. explosion

6. Acknowledgements

The research was carried out in the framework of the GINOP-2.3.2-15-2016- 00010 *Development of enhanced engineering methods with the aim at utilization of subterranean energy resources* project of the Research Institute of Applied Earth Sciences of the University of Miskolc in the framework of the

Széchenyi 2020 Plan, funded by the European Union, co-financed by the European Structural and Investment Funds.

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