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Ammonia Pressure Station in SEVESO Establishment – Case Study Focused on the Impact on the Environment

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The aim of the paper is to present Ammonia pressure station from the major accident prevention point of view. This object, located in the SEVESO establishment, present a significant source of risk which can cause serious consequences to human health and the environment in case of major accident. Ammonia, classified as a named dangerous substance, is stored in 500 kilograms pressure vessel, which is inside of the pressure station placed. The highest risk for surroundings presents transport of ammonia pressure vessel from the storage to the pressure station and transport to the storage naturally.
For purposes of completion of approved SEVESO documentation, new risk assessment had to be processed. This paper focuses in particular on the possible negative impact on the environment in case of extraordinary release of ammonia from the pressure vessel. For calculation of consequence categories of the impact on the environment was selected methodology “Hazard & Vulnerability Index”. The H&V index methodology is a Czech, official and frequently used methodology recommended especially for the environmental risk analysis in the SEVESO establishments. The benefit of this methodology is in its options to evaluate the impact to different parts of the environment, i.e. surface waters, underground waters, soil medium and biota considering diverse vulnerability of these components.
Risk analysis via the H&V index methodology follows up on the determination of accident scenarios, a stage describing different transfer routes of ammonia release to the environment occurred in the establishment. The pressure vessel is to a steel pallet attached so that it can transported in the establishment by a forklift or truck. Four different places in the establishment was determined as the worst in terms of the environmental endanger (i.e. direct and indirect endanger of the environment, transport via sewer system etc.). Consequence categories were for closed surface water and biotic environmental compartments calculated.
In conclusion, risk acceptability of determined scenarios is estimated in acceptable level. Results are presented via risk matrix recommended by H&V Index methodology. Visualization of scenarios is created by GIS. Proposed preventive measures including the way of liquidation of ammonia accidental release close this paper.

1. Introduction

Major environmental accident is defined as an occurrence such as a major emission (i.e. major release) resulting from uncontrolled developments in the course of the operation of any establishment covered by SEVESO Directive III, and leading to serious danger to the environment, immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances (European Commission, 2012). Dangerous substances and their hazard categories are listed in the Annex I of SEVESO Directive III (European Commission, 2012). Environmental hazards are defined according to hazard categories together with qualifying quantity (tonnes) of dangerous substances, where only aquatic environment is considered (Sikorova and Bernatik, 2018). Aquatic environment is the most vulnerable to the pollution from all emergency incidents (Geynes and Wood, 2014).
Lessons learned from past major environmental accidents clearly demonstrate negative impact especially to the aquatic environment. Majority of reported major environmental accident, both in the Czech Republic and

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European union, have occurred near watercourses (Sikorova et al., 2017). Plant sewer system, rainwater drainage system, wastewater treatment plant (Wang et al., 2017) and other services all present routes for the transport of pollutants off-site (De Rademaeker, 2014).

If Seveso establishment is placed close to water resources, the operator must be sure that the sewer system does not let hazardous substances leakage into the water environment directly. The operator should know the layout of the sewer system and what the intervention should look like to avoid the release outside the company. Effective prevention and preparedness to the major environmental accidents is a reflection of level of safety management system being implemented in Seveso establishment.

The sewere system in the case study is a both, process and rain. Process sewer system is primarily used for a transport of contaminated waste waters from production facilities. This sewer system is completely connected to the wastewater treatment plant located in the north part of the plant. Rainwaters are flowing by a separate sewer system. Historically, related to the development of the plant, several outflows were built. Rain sewer is from 70% protected from undesirable direct release to the river and connected to the wastewater treatment plant. However, the remaining 30% flowing right to the aquatic environment with no possibility to stop them automatically (remotely) in case of extraordinary release (Scenario no.1, manual safety valve was implemented).

2. Methodology

First method of the risk assessment, a selection of major accident risk sources was carried out using the CPR 18E Purple Book selection method. The method for identifying and selecting risk sources has been developed by the Netherlands Industrial Safety Institute (TNO) and published in the Guidelines for Quantitative Risk Assessment (Purple Book, 2005). The second method for a case study was the Czech Hazard & Vulnerability Index methodology (Danihelka et al., 2006). H&V Index is based on the evaluation of the hazard index of the substance for the environment and the vulnerability index of the territory against the potential accident involving the dangerous substance (Sikorova et al., 2017). The hazard index performs combination of the ecotoxic properties of the substance, the physical-chemical properties of the substance and the potential spread of the substance. The vulnerability index can be determined separately for the different parts of the environment (e.g. surface and groundwater, soil environment, biotic component of the landscape. It includes the characteristics of these parts of the environment (e.g. soil permeability, permeability of hydrogeological subsoil, land use, use of underground and surface water, specially protected nature areas, protection zones etc.). Using synthesis of both indexes (hazard index and vulnerability index) partial indexes are obtained that inform about the hazards of selected substance for the site being evaluated. In conclusion of the evaluation the consequence of the environmental impact is determined. Consequence (A-E) is calculated as a combination of the amount of released substance and partial indexes.

3. Case study

The assessment of a new source of risk of a major accident was carried out in a pharmaceutical company that manufactures a wide range of medicines, from generic medicines, to original and biopharmaceutical products, to active ingredients. The company is included in “Lower-tier group” (note: group A in the Czech Republic) according to the Seveso Directive (European Commission, 2012). In addition to ammonia, there are several other hazardous substances in the establishment, the sum of which determined the classification of the object into group A (e.g. methanol, hexane and other). Ammonia is used in the production process to make the original drug, the preparation of which is not made available to the public. Ammonia is used to neutralize sulfuric acid.

3.1 Risk identification

By the identification of new risk source, which can cause a major environmental accident, were determined 2 significant objects, where the ammonia can be located (see Table 1). Among the identified objects belong the cylinder storage (No. 1) and the Ammonia pressure station (No. 2) (Gerlochova, 2021).

Table 1: List of risk sources related to the Ammonia pressure station

No.	Name	State	Hazardous properties	Quantity (tonnes)	Facility
1	Cylinder storage	Liquid, gas	H410, H331, H280	0,5	Pressure vessel
2	Pressure station	Liquid, gas	H410, H331, H280	0,5	Pressure vessel

Cylinder storage is located in one-storey building, which is divided into two parts. One part is made of non-combustible materials and the other part is fenced with a roof. The brick part of the storage is divided into 8 rooms plus a service room. Various hazardous substances are stored in the brick part, e.g. nitrogen, carbon dioxide, helium. Other storage rooms have flammable and toxic substances. Each storage has a separate metal door. A reserve ammonia pressure vessel is stored in one of the eight rooms (Safety program, 2021). The pressure vessel is moved to or from the cylinder storage by a forklift. Access to the storage rooms is from the ramp.

The pressure station is located in front of the production hall in a separate outdoor building (see Figure 1). The station is situated on a concrete foundation and is locked against unwanted manipulation, which is allowed only to the operator. Inside the pressure station there is a pressure vessel which is filled with liquefied ammonia. The vessel contains 500 kg of liquid ammonia. It is placed on a steel pallet so that the container can be handled. The container is transported to the station by a forklift through the side door. It is placed on a weighing platform to monitor the current state of the pressure vessel. The data from the weighing platform is transmitted on the display located in the pressure station and in the operating area rooms (Safety program, 2021). An emergency catchment is located under the ammonia pressure station, which is dimensioned for capture of total volume of the pressure vessel.

The vessel is also connected to the pipeline leading to the production hall by a pressure hose, which is terminated by a shut-off valve. This serves to prevent ammonia leakage when containers are replaced. Ammonia is taken into operation in a liquid state during operation. The ammonia pressure is automatically maintained between 5 bar and 20 bar, which corresponds to temperatures from 10°C to 53°C. To ensure liquid ammonia even during transport to the first floor, it is subcooled below the evaporating temperature using cooled glycol (Safety program, 2021). The pressure station is equipped with continuous leak detection and an electrical fire alarm device to which a smoke detector and a water semi-stable fire extinguishing device are connected.

Figure 1: Ammonia pressure vessel and station

3.2 Scenarios

The Seveso establishment is located in the industrial area, at a distance of about 400 m from the Opava river bank and about 150 m from the highway. The nearest residential area are the family houses at a distance of about 900 meters from the northwest. The Opava River is classified as a biocorridor, as it connects several regional and supra-regional biocentres along its flow from its source to its outfall into the Odra River (note: border river flowing into Poland). The biocorridor serves to connect several biocentres and creates a network from them, which enables the migration of organisms. The biocentre is a locality in which the organisms of protected species develop, grow and multiply (European Commission, 1974 and 1992).

In case of major accident which can lead to serious danger to the environment were identified 4 accident scenarios:

- Scenario 1 [S1] - ammonia leakage into the rain sewer during the transport of a pressure vessel to a cylinder storage
- Scenario 2 [S2] - ammonia leakage from a pressure vessel located in a cylinder storage facility
- Scenario 3 [S3] - ammonia leakage into the rain sewer during the transport of the pressure vessel from the cylinder storage to the pressure station building
- Scenario 4 [S4] - ammonia leakage from a pressure vessel located in a pressure station building

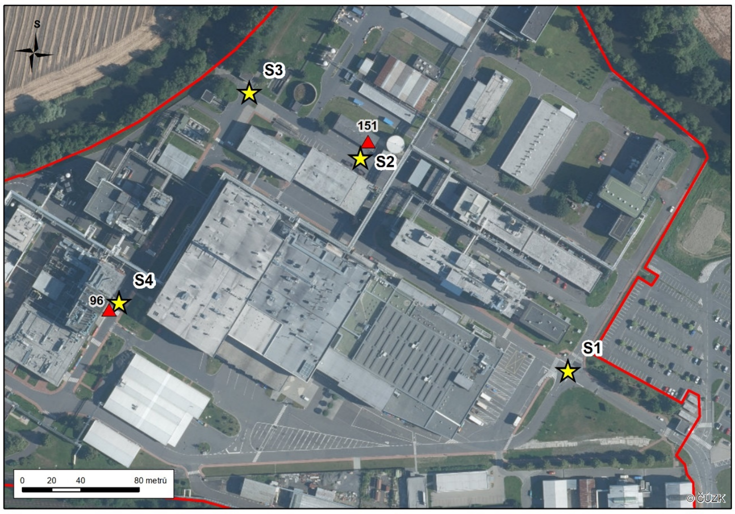

Figure 2: Location of possible ammonia leakage inside of the Seveso establishment

Estimation of the frequency of accident scenarios was carried out in accordance with Guideline for quantitative risk assessment (Purple Book, 2005). First, the LOCs for pressure vessels (stationary) are considered G.1 Instantaneous release of the complete inventory, G.2 Continuous release of the complete inventory in 10 min at a constant rate of release and G.3 Continuous release from a hole with an effective diameter of 10 mm. Frequencies of LOCs for stationary vessels were used from (seed Table 2).

Table 2: Frequencies of LOCs for stationary vessels

Installation (part)	G.1 Instantaneous	G.2 Continuous, 10 min	G.3 Continuous, ∅10 mm
pressure vessel	5×10^{-7} y^{-1}	5×10^{-7} y^{-1}	1×10^{-5} y^{-1}
process vessel	5×10^{-6} y^{-1}	5×10^{-6} y^{-1}	1×10^{-4} y^{-1}
reactor vessel	5×10^{-6} y^{-1}	5×10^{-6} y^{-1}	1×10^{-4} y^{-1}

3.3 Environmental impact assessment

H&V Index methodology was primarily developed for environmental impact assessment of short-term emergency releases into the environment with the presence of dangerous substance. The purpose of this methodology is a risk analysis related to the major accident from which follows the possibility of environmental threat. If the parts of the environment are not seriously affected, they will not be evaluated (Sikorova et al., 2017). Due to the classification of ammonia as a hazardous to the aquatic environment with long lasting effects (H410), the environmental impact assessment was focused on the impact on surface water in this paper. Other possible impacts on the soil environment and groundwater can be characterized as negligible as there will be no possibility for the absorption of liquid ammonia into the subsoil near the storage site.
In the first step, hazard index T_W – Index of toxic hazard to the aquatic environment was calculated as a combination of acute toxicity and selected physical properties of substance ($T_W = 5$), where resulted index 5 performs very high toxicity to the water environment.
The second step was to assess vulnerability to surface water, as this environmental compartment is most at risk from possible release of hazardous substances that are classified as toxic to aquatic organisms and may cause long-term adverse effects in the aquatic environment. For scenarios S1 a S3 was final vulnerability index determined as $I_{SW}= 3$ due to possibility of release via rain sewer. For scenarios S2 a S4 was final vulnerability index estimated as $I_{SW}= 1$, which represents release to sewer connected with site wastewater treatment plant.
By synthesis of indexes, both hazard and vulnerability indexes (T_W and I_{SW}), a final index of toxicity to the aquatic environment (I_{TSW}) was calculated (see Equation 1 and Table 3).

$$I_{TSW} = max\left(\frac{Isw + Tw}{2}\right) = \left(\frac{3+5}{2}\right) = 4$$

$$I_{TSW} = max\left(\frac{Isw + Tw}{2}\right) = \left(\frac{1+5}{2}\right) = 3 \qquad (1)$$

In conclusion, consequence categories depending on considered amount release (Am) and toxicity to the aquatic environment (I_{TSW}) were estimated (see Table 3). Resulting consequence categories (A-E) perform the prediction of the impact to the aquatic environment, where "B category" presents small impact to the river, "C category" significant impact, "D category" very significant impact and "E category" maximal impact.

Table 3: Categories of major accident consequence caused by ammonia release to surface water

		Amount of leakage [tonnes]				
		<1	**1-10**	**10-50**	**50-200**	**>200**
I_{TSW}	**1.**	A	A	B	B	C
	2.	A	B	C	C	D
	3.	B	C	C	D	E
	4.	B	C	D	E	E
	5.	C	D	E	E	E

For accident scenario of leakage of maximum 0,5 tonnes of ammonia from the pressure vessel was estimated the consequence category "B" presenting the small impact on surface water. The final B category was calculated for all scenarios, i.e. from S1 to S4. The acceptability of scenarios was estimated by using a risk matrix (see Figure 3) included in H&V index methodology.

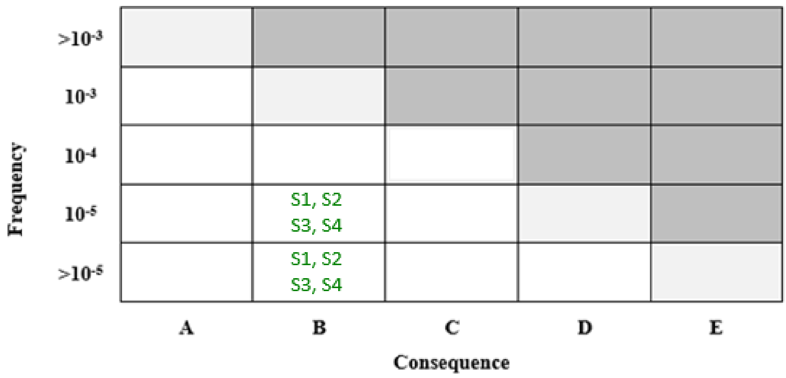

Figure 3: Risk matrix used for evaluation of scenarios acceptability with the impact to the aquatic environment

4. Conclusion

This paper contains results of case study aimed at environmental risk assessment of new risk source located in Seveso establishment, i.e. Ammonia pressure station. Results obtained form case study were implemented to the safety documentation, which then needs to be approved according to the rules following from the Seveso Directive (European Commission, 2012). In the graphic part of case study, the places where the pressure vessel is stored and where is transported were specified. It has been determined that transportation of pressure vessel, inside of the company, represents significant source of risk of major environmental accident. Whereas the location of Seveso establishment is close to the river and the companies rain sewer is connected to the river, case study was directed at risk assessment with negative impacts to the surface waters.
Overall, 4 emergency scenarios were identified, which can actually lead to major environmental accident due to release of ammonia from the pressure vessel. The frequency of ammonia accident was taken from the Purple Book. First, the instantaneous release of total volume of ammonia from pressure vessel, as the worst accident scenario, was considered. Then was calculated with the continuous release, which distinguished according to

the hole diameter between 10 cm and 1 cm in the vessel. Resulting frequencies together with final consequences were put to the risk matrix recommended by H&V index methodology. All scenarios were evaluated as an environmentally acceptable.

Scenario [S1] can be prevented by well-timed closing of the rain sewer with a safety valve, and subsequent pumping into the operational sewer leading to the waste water treatment plant (WWTP). An effective measure is to ensure a functioning management system for the prevention of major accidents in the company. The pressure vessel is transported by an external company, it would be appropriate to acquaint the truck driver with these scenarios in the form of training, so that he knows how to proceed correctly and safely in the event of an emergency. If the ammonia did release into the river, the Fire and Rescue Service of the Moravian-Silesian Region would intervene.

In case of scenario [S2] ammonia will release into the operational sewer, which is connected with the WWTP. If contaminated water needed to be drain away from the sewer, the Fire and Rescue Service of the company, which is sufficiently equipped to deal with these emergency situations, will intervene. For liquidation of the ammonia cloud, sprinklers will be used and contaminated water will be catched to avoid release into the environment.

When scenario [S3] occurs, the location of the company's Fire and Rescue Service is a benefit for purposes of immediate intervention. This station is located closed to the Ammonia pressure station. In case of undesirable release of ammonia into rain sewer, the firefighters will use sewer seals, which they are sufficiently equipped.

The preventive measure for this scenario can be considered a staff training again. In this case, the training of forklift driver.

Last scenario [S4] considers the release of ammonia into emergency catchment situated under the Ammonia pressure station. This preventive measure is dimensioned for total volume of ammonia pressure vessel, e.g. 500 kilograms. Here will intervene company's Fire and Rescue Service too. Contaminated water pumped out from the catchment will be taken to liquidation to WWTP.

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