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Preparedness of SEVESO establishment for NATECH accident - lessons learned from floods in 2024

Katerina Sikorova

Department of Occupational Safety and Processes, VSB – Technical University of Ostrava, Czech Republic. E-mail: katerina.sikorova@vsb.cz

Katerina Blazkova

Fire Rescue Service of the Czech Republic, Czech Republic. E-mail: katerina.blazkova@hzscr.cz

Tomas Nedelka

Department of Occupational Safety and Processes, VSB – Technical University of Ostrava, Czech Republic.

Natural hazards can cause Natech accidents by triggering dangerous events such as fire, explosions, and toxic releases in industry. As a result of the Natech accidents, a significant loss of life, environment, and property is experienced. Natech accident, which occurred in the industry, can be classified as a major accident according to European regulation SEVESO Directive (EC, 2013). Therefore, it is extremely important to pay attention to risk management of Natech accidents. With the expected increase in intensity and frequency of natural events from climate change, Natech risks presenting increasing concern in risk prevention and risk management at local, national and international level (EC, 2020).
This paper is focused on selected natural hazards–floods, which directly endangered SEVESO chemical plants in 2024 in the Czech Republic. The floods began on Friday, September 13, as a result of the collision of two frontal systems over the Central European area, which brought persistent rain. They affected most of the territory of the Czech Republic, its neighbouring countries, as well as Croatia and Romania. A total of 262 watercourses reached one of the flood degrees (from 1 to 3 level). More than 55 measuring points recorded 100-year water level. The experiences and lessons learned from the floods occurred in 1997 and 2002 on the territory of the Czech Republic, significantly contributed to minor losses to the surroundings as a result of uncontrolled chemical substance releases. This paper discusses the occurrence of Natech risk - floods in the Czech Republic from the perspective of Seveso establishment, gives examples from the past and proposes a way of prevention, preparedness and mitigation. It concludes with recommendations on how to prepare for floods that can reoccur in future.

Keywords: Natech accident, Floods, Major accident, SEVESO facility, Risk management.

1. Introduction

In 2024, the Czech Republic experienced another devastating flood, which severely affected several regions. The cause of the intense rainfall that led to the floods in September 2024 was the low-pressure system Boris, which moved from northern Italy into the region of Central and Eastern Europe. The flood, which began on September 13, its catastrophic course, along with the resulting property damage, is comparable to the floods of 1997 and 2002. The most affected areas were the Moravian-Silesian and Olomouc regions. The total average precipitation in the Czech Republic for September 2024 reached 179 mm (which is 298 % of the 1991–2020 average). This makes it the second highest monthly precipitation total in the Czech Republic since 1961. The only higher monthly total (204 mm) was recorded in July 1997. During the six-day period from September 11 to 16, the rainfall amounts reached extreme levels, especially in the Jeseníky Mountains. The record fell in the village of Loučná nad Desnou, where 704.2 mm of rain fell during this period. To put this into perspective, the long-term precipitation norm in the Czech lowlands is just slightly over 400 mm. This means that, in just a few days, more rain fell

in the Jeseníky Mountains than in these areas over an entire year.

Without a quick and adequate response to this extreme flood, the damage to property and lives would have been much greater. The floods caused extensive damage to infrastructure, destroying roads, bridges, and many buildings. Some towns were flooded by more than 80% (Krnov, Opava, Ostrava etc., and several thousand people had to be evacuated (see Fig. 1). In the affected areas, there were power outages, and road and rail transport were disrupted. International train services between the Czech Republic and Poland also had to be suspended. The damage calculated so far exceeds 60 billion Czech crowns, though this amount is still not final. Unfortunately, this event was not without human casualties; the floods claimed the lives of 15 people. While the intense rainfall caused the most significant damage in the Czech Republic, it was not the only affected country. In addition to our neighbors Poland, Austria, and Slovakia flooding also affected Slovenia, Romania, and Croatia. Germany also faced complications, as it was later threatened by elevated levels of the Elbe River. Increased concerns during the floods in September 2024 were triggered by the breach of a dam at the confluence of the Odra and Opava rivers, which unexpectedly flooded residential areas and businesses in Ostrava, particularly in the districts of Privoz and Marianske Hory (see Fig. 1). Due to the flood, two Ostrava district heating plants operated by Veolia and the local coke oven OKK were shut down. For safety reasons, the BC MCHZ SEVESO chemical plant in Ostrava was also taken offline.

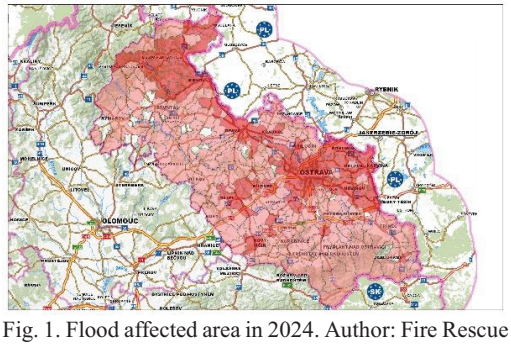

Fig. 1. Flood affected area in 2024. Author: Fire Rescue Service of Moravian-Silesian Region.

Fig. 2. Aerial view of the floods in Ostrava in 2024. Author: idnes.cz

This paper is focused on floods, which directly endangered SEVESO chemical plant in 2024 in the Czech Republic. SEVESO establishment means the location where selected dangerous substances are present in one or more installations (EC, 2013). Preparedness of SEVESO chemical plant for floods is embedded in the SEVESO Directive (EC, 2013) via required emergency plans and in the Floods Directive (EC, 2007) through required flood risk management plans showing the potential consequences associated with different flood scenarios on flood hazard or risk maps. These plans include information on potential sources of environmental contamination as a consequence of floods. Floods that led to major accident in the past have been described, for instance, in (Danihelka et al., 2006; Geynes and Wood, 2014; Sikorova and Bernatik A, 2012).

2. Methodology for Natech risk assessment

Natural hazards, such as floods, can trigger major accidents at SEVESO establishments These technological "side effects" of natural-hazard impacts are called "Natech" accidents (from "natural-hazards triggered technological accidents"). With the evident increase in intensity and frequency of natural events from climate change, Natech risk is an increasing concern in major accident prevention and risk management at local, national and international level (EC, 2020). SEVESO Directive explicitly introduced Natech risk as an important component of a dangerous site's overall risk management strategy for upper tier sites in the safety report (Annex II of the Directive).

The Czech Republic, as well as other European countries, is involved in international activities in the area of "Natech accidents", which are in particular the OECD Programme on Chemical Accidents (OECD, 2024), the International Convention on the Transboundary Effects of Major Accidents (UNECE, 1992), the Sendai Framework (United Nations, 2015) and Floods Directive (EC, 2007). In relation to these documents, Czech Decree No. 227/2015 requires the operator of a facility falling within the scope of the Act on the Prevention of Major Accidents (Ministry of Environment, 2015) to: list potential natural hazards that may cause a major accident or worsen its course (Natech risks) in the safety documentation. In relevant scenario cases, the operator should then consider the effects of the identified Natech risks and apply adequate measures to treat them, for example in accordance with the recommended risk management cycle according to ISO 31 000:2018. These requirements are elaborated in the form of methodological guideline of the Ministry of Environment for determination of Natech risks according to the Act on prevention of major accidents caused by hazardous chemical substances (Ministry of Environment, 2023). For the needs of Natech Risk Management is recommended to use a Guideline for operators of hazardous industrial sites and for national authorities (Necci and Krausmann, 2022). Further information focused on Natech accident issue can be found in and following papers (Krausmann, E. et al., 2019; Krausmann and Necci, 2021; Ricci et al., 2021; Necci and Krausmann, 2022) and eNatech database (eNatech, 2024).

3. Case study – floods in the Czech Republic

Floods represent the greatest direct danger for the Czech Republic in the area of natural disasters and are the cause of serious emergency and crisis situations. These events are accompanied not only by extensive material damage, but also by loss of life and extensive devastation of the cultural landscape, including environmental damage (De Rademaeker et al., 2014; Geynes and Wood, 2014; Sikorova et al., 2017a; Krausmann, E. et al., 2019). Current data and prognoses show that the frequency and intensity of natural risks associated with climate change will increase in the coming decades in the Czech Republic too. Some types of natural hazards may occur in places of the Czech Republic where they have never occurred or been never observed in the same region before. Therefore, it is important to be prepared to them using lessons learned from past events (Sikorova and Bernatik, 2017b).

3.1. Floods in the Czech Republic and Spain in 2024

In October 2024, the region of Valencia in Spain was also significantly affected by the worst floods ever, i.e. shortly after the floods have hit the Czech Republic. The number of death people exceeded a hundred and rescuers searched for a next number of missing people in flooded houses or cars.

Weather forecasts were correct, but it was general, the rainfall was not shocking in itself, but it did hit a densely populated area. According to report of Czech Hydrometeorological Institute (CHO, 2024), the floods were caused by a well-known phenomenon called “cold drop”. This effect is related to the jet stream, which is representing by a high-altitude flow from five to ten kilometres above the surface that separates the very cold air in the north from the warmer air in the south. In Spain, a parcel of cold air was 'ripped off' through the jet stream and then travelled across the north-east Atlantic and the British Isles to the Mediterranean, before holding over Spain. It's not even noticeable at ground level because it's normally warm there and the cold air stays at higher altitudes. However, a chimney effect is created where warm air rises upwards, meets a package of cold air and creates convective cloud cover which has brought extreme torrential rainfall and flooding to Valencia.

In the Czech Republic meteorologists predicted the Jeseníky Mountains to be the most affected. The Spanish meteorologists predicted Valencia region. Both came true, but the big difference was that while in the Czech Republic the Jeseníky Mountains were really affected as a whole, in Spain there was a significant spatial variation in rainfall.

In this type of natural hazards, it may really occur that, for example, one valley, where one smaller watercourse spills out, will be completely devastated, while nothing special will happen in the neighbouring one. However, it is impossible to predict in advance which specific parts of the area at risk will be affected.

In both cases of flooding, in the Czech Republic and in Spain, it was extreme rainfall, but

these normally occur in the Mediterranean. While in the Czech Republic has been reached a daily rainfall record of total 386 mm. In Spain has fallen around 320 mm in a few hours in one place. In the Mediterranean area, rainfall records usually reach above 400 mm and sometimes even 600 mm.

Heavy rainfall in Spain hit a densely populated area. The landscape in the Mediterranean cannot usually hold large volume of water, so water runs off very quickly. If rainfall hit a densely populated area, it unfortunately means a big threat to human health and lives.

The high sea temperature, which increased the temperature difference between the lower and higher areas, clearly contributed to the flooding. In summary, climate change may have played a significant role in both floods.

3.2. Preparedness of SEVESO establishment for floods

Chemical companies, including SEVESO establishments, need a significant amount of water for their complex operation and especially for their technology. They are therefore strategically located near watercourses to ensure that the water source is as close as possible and that water transport through pipeline systems and water intakes is as short and economical as possible. If a company is located close to a watercourse, it must consider that its territory may be threatened by the negative effects of flooding. In case of chemical plants classified according to SEVESO Directive, there is a need to involve Natech scenarios in safety documentation and analyse them from the view of resulting prevention and preparedness for major accidents.

During floods occurred in the Czech Republic in 2024, the BorsodChem SEVESO chemical plant in Ostrava was significantly flooded. This upper-tier SEVESO establishment is one of the two production plants of the BorsodChem Group in Central Europe, owned by the Chinese company Wanhua. The company provides supply a range of products mainly organic but also inorganic in nature. Among selected dangerous substances located in the plant belong ammonia, aniline, nitrobenzene, cyklohexylamine and others. The company has its own smaller waste water treatment plant (WWTP). Wastewaters from the production units are daily analysed in the laboratory and after the analysis they are treated at the WWTP, where they are discharged into the receiving water after treatment through an open wastewater channel.

BC MCHZ is located in the northern industrial zone of Ostrava, on the right bank of the Odra River, just below its confluence with the Opava River (about 300 m from the confluence of the Opava and the Odra). This location belongs according to flood risk management plans to the area with a high probability of occurrence of floods (see Fig. 3) and it also became fatal for this SEVESO company at the time of the floods in September 2024 (see Fig. 4).

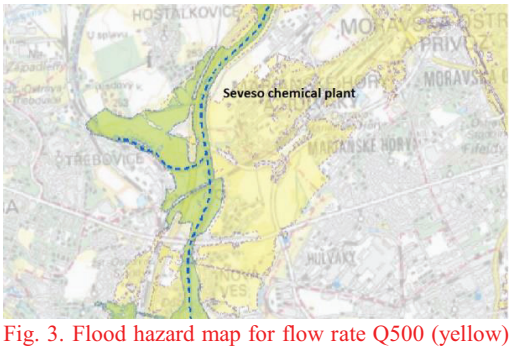

Fig. 3. Flood hazard map for flow rate Q500 (yellow) and Q100 (green) illustrating flooded Seveso plant; scale 1:10 000. Author: Czech Ministry of the Environment.

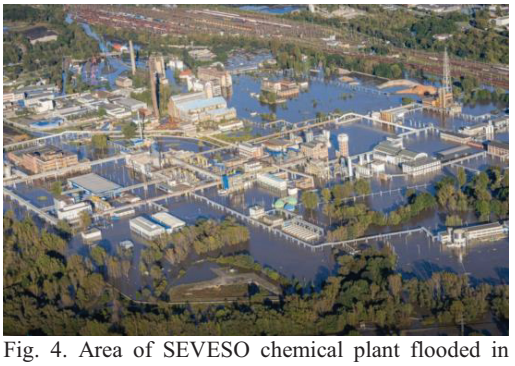

Fig. 4. Area of SEVESO chemical plant flooded in 2024. Author: idnes.cz

Flood protection measures:

Basic measures, activities and recommendations during flood activity are included in the company's Flood plan. This plan is followed by the Specific Flood Activity Plans designed for production and non-production departments. The goal of these plans is to specify the activities in 3. level of flood activity for production units and other departments of plant and to ensure their mutual coordination and communication with the control room.

Following resources for flood prevention and preparedness can be used during an emergency situation:

- **motor or motor less boats (rafts)**

SEVESO chemical plant is characterized by a large number of pipelines, process equipment and other technical and construction elements that extend to different horizontal levels. When the plant is flooded by a flood wave, some of these structural and technological elements are hidden below the surface and make it very difficult to move around the area. When carrying out rescue work on the water surface using a motorboat, there is a considerable risk of collision with flooded parts of the technology and destruction of the drive. Even for the company's employees, orientation in the flooded area is considerably complicated, and they often prefer to explore the area with the engine switched off. The solution for these situations is to acquire a non-motorised boat - raft, which can be operated with paddles or, when the water level is calm and up to about 1.2 m, can be moved by a person moving on the ground. In such a case, it is possible to move very slowly and cautiously and to reach sections where manoeuvring with a motorboat is very difficult or impossible.

- **emergency shut-offs in sewer system**

The emergency stoppers, implemented e.g. in BC MCHZ, are manually closable sewer bulkheads that serve to separate individual sewer branches from the main sewer. The principle is the same as in case of a gate valve. The gates are operable from the surface, so there is no need to enter the sewer manhole. In addition to preventing release of dangerous substances, these gates can also be used during floods.

- **safety procedure for pumping dangerous substances** into cisterns and transporting them out of the endangered area

For example, BC MCHZ is a processor and manufacturer of dangerous substances transported cold, i.e., they do not require reheating. Transportation of dangerous substances is provided by rail or road cisterns where the majority of them is NL transported via railways. Only special wagons whose surfaces are specially treated (rubberised) or made entirely of a material resistant to aggressive substances (Cr-Ni alloy steel) may be used for the transport of these dangerous substances.

Time needed for cistern filling process or process of emptying the dangerous substance from the tank depending on pump power and physical-chemical properties of substance, e.g. see Table 1 and 2. Further detailed data are shown in (Novacek, 2009).

Table 1. Time needed for filling process into cisterns (min)

Volume (l)	Pump power ($l.min^{-1}$)			
	200	500	1000	2000
1000	50 min	20 min	20 min	5 min
2000	100 min	40 min	20 min	20 min
46000	220 min	92 min	46 min	23 min

Table 2. Time needed for empty process from the tank (min)

Volume (l)	Pump power ($l.min^{-1}$)		
	500	1000	2000
361 *Aniline*	722 min	20 min	5 min
240 *Ethanol*	480 min	240 min	120 min
380 *Cyklohexylamine*	760 min	380 min	190 min

- **safety procedure for filling tanks with water** (i.e. empty even half-empty tanks),

Storage tanks are the most endangered facility during the floods because of their subtitle low-weight packaging structure. Storage tanks located in SEVESO establishment perform generally standing or lying cylindrical vessels. During a flood, the water level may rise above the base structure of the storage tank and apply a pressure and buoyant force directly on the container body. If the effect of these forces is greater than the gravitational forces induced by the weight of the tank and the pressure force exerted on the tank walls inside, the tank will be detached from the foundation structure or their walls will be deformed.

If the tank is empty and its design allows it, it can be filled with water. By disassembly of the manholes or shut-off valves on the pipeline will be created openings through which water can enter the interior space. The level inside and outside the tank will equal and the forces acting on the tank will be in balance.

In the case of such a tank design that the openings for the flood water are too high and

destruction of the reservoir would be imminent before the water level reaches this opening, it is recommended to create a pipe branch on the tank, completed with a valve where fire hoses can be immediately connected and the tank can be filled with process or fire water.

If tanks involving same substance and are half empty, it is recommended to combine their volumes into smaller number of tanks and only empty tanks fill with water.

If none of the above proposals can be implemented, as a last possible step, water can be flooded into the tanks that are not empty. In this case, the reaction of water and dangerous substance must be considered. This approach will lead to degradation of dangerous substance in the tank, but the construction of the tank will be protected and the dangerous substance remains inside of the tank. During the extraordinary event this solution is more acceptable than if the destruction of the tank resulted in release of dangerous substance into surrounding and caused major damage to the environment.

- **use of mobile flood barriers**

In SEVESO chemical plant where there is a risk of known damage or where it is not possible to implement in any other way of flood protection (facility cannot be dismantled, storage tank cannot be emptied, etc.) it is possible to build mobile barriers as way of protection against the advancing flood wave. On the market today, there are many manufacturers who are able to design and supply flood barriers according to requirements of the customer's needs. If BC MCHZ would decide to apply mobile barriers around the most vulnerable part of the chemical production process, it would be length of approximately 1580 m.

- **and others** (pumps - submersible, floating, portable, power station - 4 and 6.5 kW, bags with sand float, jackets, ladders, ropes or connection technology – mobiles, walkie-talkies)

In events that it is not possible to mix dangerous substance with water or the time needed for emptying, filling or transporting the facility to protected area is insufficient it can be recommended to create a construction solution of the tank (see Fig. 6) which will protect both the tank and dangerous substance located inside.

The design of the tank, as a pontoon, is particularly suitable for the lying cylindrical vessels. A schematic drawing and the principle of this solution for ammonia tanks in BC MCHZ was proposed by Novacek (2009) and is shown in Fig. 5. Each of 9 tanks has an internal volume of 103 m^3 of ammonia. According to ammonia dangerous properties and present technology, it is not possible to implement none of the above safety measures.

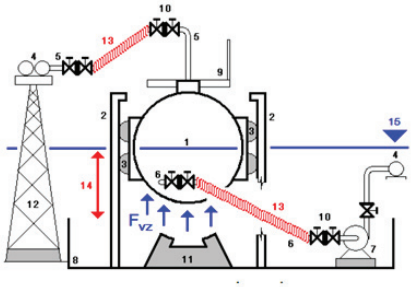

Fig. 5. Pontoon storage tank for hazardous substances (Novacek, 2009)

3.4. Floods from the view of Fire Rescue Service

The year 2024 has been full of emergencies for Czech firefighters It was exceptional in terms of the number of interventions, but also in the deployment of up to a third of all firefighters during September's extensive floods. This natural disaster showed good preparedness of the Fire Rescue Service, but also a number of gaps that need to be solved in future.

The early prediction by the Czech Hydrometeorological Institute helped the Fire Rescue Service significantly. Warnings have started from 11th of September. and gradually increased up to extreme danger level announced in 13th of September. The prediction has become a reality. Several watercourses exceeded 3rd flood activity level during 13th and 14th of September. State of emergency, i.e. crisis situation was announced on 14th of September. In the territory of Moravian-Silesian Region, which was one of the most affected regions, were 282 towns and villages (from a total of 300) hit by an extreme flood like never before in history. Among the most affected belonged Krnov, Opava, Ostrava and Bohumin. It was Ostrava that its industrial part was significantly flooded as a result of

disturbance of flood protection measures at the confluence of the rivers Odra and Opava. SEVESO establishments – BC MCHZ and coke plant OKK stayed flooded for several days. Due to early warning from Czech Hydrometeorological Institute and preparedness of the company on Natech accident (according to Emergency Plan and Flood Plan) together with lessons learned from flood in 1997, was industrial zone of Ostrava shut down in time a safely. No major release of dangerous substance was reported. Nevertheless, as a result of flooded huge industrial part of Ostrava, floods caused in Seveso establishments these major consequences:

- significant property losses,
- shutdown and inability to produce for months,
- loss of heat supply (for the whole city Ostrava) due to flooding of heating plant,
- extensive and costly maintenance of all flooded facilities and equipment (e.g. motors, compressors, pumps, electro equipment etc.
- flooded company WWTP together with hazardous waste incineration plant and urban WWTP for city of Ostrava.

4. Conclusion

Floods occurred in 2024, both in the Czech Republic and Spain, were influenced by climate change which contributes to the formation of natural hazards on the territory. According to statistics in eNatech database (eNatech, 2024), Natech accidents are not as frequent as ordinary releases of dangerous substances occurring in Seveso establishments, but their consequences are in enormous scale. Natech accidents, and the risks associated with them, are already a part of the risk assessment and risk management processes in the SEVESO industry. Industrial facilities that handle dangerous substances are vulnerable to the impacts of natural hazards. Due to Natech risk assessment and management involving in safety reports together with lessons learned from past natural events it can be declared, that SEVESO establishments with integral support of Fire Rescue Service are well prepared.

According to the data from Fire Rescue Service, 5235 persons were evacuated (including rescue by boats and helicopters); in total 14 000 evacuated persons (involving the number of self-evacuation). In industrial zone, facilities with dangerous substances were safely shut down due to sudden release to surrounding. No major accident occurred. Today it is necessary to focus on secondary negative impacts to human health and lives and environment caused by floods in September 2024. The threat of ecological damage in case of flooded urban WWTP (the biological part is still not working) is still running. Important it is to accept the lessons learned from these floods to be better prepared for future natural hazards that can occur in the territory of the Czech Republic, in the worst scenario with low warning as it was during the floods in 2024.

On the base of first evaluation (note: Final report was not already finished and submitted to the Czech Government) from the view of flooded SEVESO establishments and Fire Rescue Service we can make the following recommendations and lessons learned:

- checking Flood plans, Emergency plans,
- new meetings on level of flooding commission and emergency commission,
- set up a communication system using satellite communication, starling, mobile BTS, the need to increase the capacity of mobile operators,
- requirement for dynamic modelling in flood plans according to user parameters,
- education - public and professional - in relation to the strategic level of management and flood protection,
- SEVESO companies need to be prepared for situation on more than Q100 – plans, training
- solve the problem of flood waste,
- data sharing and communication - from forecast to response,
- in conclusion, being prepared is essential - having a realistic documentation base, a practiced system, resources and trained staff.

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