

ENVIRONMENTAL CHEMICAL DISASTERS AND AN EXAMPLE OF SECURITY REPORT

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Abstract Many industrial incidents, which have taken place since the seventies of the last century onwards, have raised many questions and conclusions. These disasters have shown that it is a human, a key risk factor for the survival of all living on our planet. The very approach to the prevention and recovery system proved to be frivolous, careless, and full of holes, and as a result, we got the devastating consequences. After these incidents, the environmental awareness and acceptance of the domino effect, which they carried with them, arose. When an industrial accident occurs, it causes people's death and affects the economy, social stability, and endangering the environment and biodiversity. Therefore, in the prevention process and various laws and directives, with the development of technology, there is also the development of computer programs to anticipate possible hazards and speed up the repair of the problem when this happens.

Keywords:

environmental disasters, chemical disasters, ALOHA program, ALOHA report.

1 Introduction

Human civilization's development led to humankind's unparalleled progress, recognized in the improved quality of the standard of living. However, this development also triggered many substantial environmental issues and imposed a significant threat to planet Earth's sustainability. This is quite understandable, having in mind that "(...) everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. To pursue sustainability is to create and maintain the conditions under which humans and nature can exist in productive harmony to support present and future generations" (Foray & Grübler, 1996; Marsh, 1864; United States Environmental Protection Agency [EPA], 2011; EPA, 2020a). In this way, the modern societies, as well as individuals, are facing "numerous problems, contradictions, risks, and uncertainties related to further global" sustainable development (Petković et al., 2019). These issues are evident in the environment, where we witness the worsening of environmental conditions (Maletič et al., 2017). The concept of sustainable development starts to hold the necessary and well-deserved place regarding its efficient and long-term potential. Simultaneously, it is the only principle that secures the sustainability of the expanding world population and economy that increased inefficient consumption of natural resources (Smyth, 2004). For these reasons, Sachs (2015) calls the modern age – The Age of Sustainable Development, while the 21st century "seeks to redesign the way that natural resources, materials, and energy flow through society" (Petrovic et al., 2016).

Unfortunately, all human activities negatively affect the environment to a greater or lesser extent. Among those, the following ones stand out concerning the intensity of a degree of environment degradation: energetics (nuclear energy included), industry, transport, agriculture, urban development, tourism and recreation, forestry, fisheries, and aquaculture. These activities are known as environmental stress triggers (release of pollutants into the air and water, waste, noise, radiation, chemicals, natural and technological dangers (Petrović, 2016).

It should point out that the size and the scope of environmental problems directly connect with the selection and use of technologies, even more so since the effects of scientific and technological development are now visible more than ever (Kaushik & Kaushik, 2010; Petrović, 2002). This is the reason why, in the context of

environmental pollution and negative consequences of human activities on nature, we certainly have to mention the “paradox of technological development,” as explained by Gray (1989) in the same-titled paper. This paradox refers to the relationship between technology development and nature, knowing that the technology has “a dual nature concerning the environment: Technology has had an unprecedented impact on the environment, primarily through productivity increases that enabled substantial expansion of output (and consumption)” (Foray & Grübler, 1996). The chemical industry went through expansive growth and became an inseparable part of modern living thanks to its products, at the same time producing various chemical pollutants that represent the main cause of damage to human health and the environment worldwide (Petrović, 2016).

For all the above-mentioned reasons, this paper will present the effects of chemical industry catastrophes on the environment and entire ecosystem, to stress the importance of the application and development of the system for prevention of accidents within the industry, based on the case study of the application of ALOHA program and ALOHA report. This is important since “it is necessary to establish and apply safety and risk-reduction measures to prevent possible accidents, to reduce the risk of accidents occurring and to minimize the effects if they do occur, thereby making it possible to ensure a high level of protection (...)” (Seveso II Directive 2012/18/EU, 2012).

The paper used the 5.4.7 ALOHA version on the example of EPS RB “Kolubara” d.o.o. – “Kolubara-Prerada”.

2 Chemical industry and accidents in the chemical industry

Environmental crises occupy the central position amongst all existential crises of modern civilization, thus negatively affecting the 21st century. In contrast, the growing number of world environmental problems is often interpreted as a progressive loss of ecological stability (Simonis, 1990).

Unfortunately, the chemical industry and its activities are high-risk industries in terms of the environment due to substances used in the process. They can often represent a danger in accident situations since they are usually located within densely populated areas (Malich et al., 1998; Reniers et al., 2006). “Many flammable, toxic,

and explosive chemicals are stored and used to produce compounds in chemical industries. These materials can cause hazards resulting in danger for human health and the environment. The equipment failures, natural disasters, fires, and technical problems can be the reason for hazardous industrial accidents” (İskender, 2020; Rollinson, 2018).

Unfortunately, over the last decades of humankind's history, serious accidents occurred within many industrial plants, causing the loss of human lives, permanent damage to human health, and hazardous pollution of the environment (Gomez et al., 2008). This has led to heightened society's “awareness of the negative effects of technology” (Dakkoune et al., 2018; Nivolianitou et al., 2004).

For these reasons, the United Nations (UN) Report “The Global Chemicals Outlook II – From Legacies to Innovative Solutions: Implementing the 2030 Agenda for Sustainable Development, mandated by the UN Environment Assembly in 2016, seeks to alert policymakers and other stakeholders to the critical role of the sound management of chemicals and waste in sustainable development. It takes stock of global trends as well as progress made and gaps in achieving the global goal to minimize the adverse impacts from chemicals and waste by 2020.”¹ (United Nations Environment Programme [UNEP], 2019).

The worst chemical disasters that made a permanent mark in the history of humankind and had a significant negative influence over the environment were:

- Flixborough (1974),
- Seveso (1976),
- Bhopal (1984),
- Basel (1986),
- Mexico (1988),
- Enschede (2000), and
- Toulouse (2001).

Chemical accidents in Seveso, Bhopal, and Basel certainly had the worst consequences of all.

¹ The full Global Chemicals Outlook II is launched electronically on 29 April 2019 in Geneva, Switzerland.

2.1 The Seveso disaster

Seveso is a small town in Italy, near Milan. The chemical plant Ismesa² exploded in July 1976, creating a cloud of toxic gasses (dioxin) that contaminated populated areas about 8km long.

This caused the following consequences:

- It exposed around 30,000 people to health risks.
- Over 700 inhabitants were evacuated on a long-term basis.
- Around 70,000 animals died (most of them died instantly, while the rest died later as a consequence of intoxication).

“After this accident, 82/501/EEC Directive (SEVESO I) released by the European Union for control and prevention of major accidents, SEVESO II released in 2012, and Seveso III replaced by SEVESO II in 2016” (Rollinson, 2018).

2.2 The Bhopal disaster

In the series of tragic disasters within the chemical industry, the most severe was the one that happened in Bhopal (India). In December 1984, about 40 tons of toxic gasses (methyl isocyanate, methylamine, chlorine, and phosgene) had leaked into the pesticide plant atmosphere.

The consequences were as follows:

- Around 15,000 people died immediately during this accident, or they died later of the consequences – out of this, 3,000 people died within the first week, 30% were children.
- Approximately 250,000 people asked for medical help, out of which 2,000 were severely poisoned with small survival chances.
- Out of nearly 2,700 pregnant women, almost 500 (around 20%) lost their babies.

- In the years following the disaster, around 8,500 people were registered with mental disorders.

2.3 The Sandoz fire

In October 1986, an explosion occurred, followed by a fire in Sandoz's chemical plant (Schweizerhalle, Basel, Switzerland). The fire caught the warehouses that contained great amounts of toxic substances (insecticides, herbicides, fungicides, and various mercury compounds). High temperature (over 1,000°C) initiated the blending of toxic substances later discharged into the Rhine river. At first, around 150 tons of toxic compounds leaked into the river together with the water used for putting out the fire, after which several more tons were discharged (mercury together with phosphate compounds).

This had led to the following consequences:

- Around 500,000 fish went extinct, along with the great number of birds that ate the fish.
- Complete aquatic and inshore biocoenosis was destroyed, leading to a reduction in biodiversity.
- Water supply was compromised in many towns along the shore of the Rhine.

The entire situation was further aggravated by the chemical industry “Ciba-geigy” which saw this as an opportunity to dispose of 400 liters of toxic atrazine pesticides. Later analyses concluded that this release polluted the river by 100 times higher concentration than tolerable to the river ecosystem. The accumulation of toxic substances along the riverbed later led to the reactivation of these substances and river pollution triggered by snow melting and river tributaries. It was also hard to assess the quality and quantity of substances released into the atmosphere, only to end up on the ground and surface waters.

3 Methodology

“ALOHA (Areal Locations of Hazardous Atmospheres) is an atmospheric dispersion model for the CAMEO software suite. It is being used primarily for the evaluation of the downwind dispersion of a chemical cloud based on the physical/toxicological characteristics of the released chemicals, atmospheric conditions, and specific circumstances of the uncontrolled release” (EPA, 2020b; EPA, 2021; Office of Environment, Health, Safety & Security, 2021).

The time of hazardous chemical emission varies from one minute up to an hour. This program allows the entry of data on real or potential chemical releases. Threat zone estimates are displayed in the ALOHA program and can be pasted onto various mapping programs, including MARPLOT map, Esri ArcMap, and Google Earth (EPA, 2021).

The red threat zone represents the worst hazard, while the orange and yellow threat zones represent lower-risk areas. The paper continues to use ALOHA version 5.4.7.

The date of the potential hazardous event is arbitrary, and all meteorological data have been pulled from the report of the Republic Hydrometeorological Service of Serbia for 2014. We chose this particular year because of the floods that hit the Republic of Serbia and increased the threat risk. Data on EPS RB “Kolubara” d.o.o. – “Kolubara-Prerada” have been downloaded from the Company’s official site.

4 Results and Discussion

4.1 The ALOHA report for EPS RB “Kolubara” d.o.o. – “Kolubara-Prerada”

A processing plant is an organizational unit of the Kolubara mining basin. This is where the processing of coal from the open cast mines takes place. The products are then used for the supply of industries, thermal power plants, and households. The coal refining plant consists of two operational units: Drying Plant and Wet Separation. During the dry separation process, the coal is crushed and sorted out. The Wet Separation Plant is found within the Coal Refining Plant. Here the coal is refined using water, and impurities are being removed. The refined coal is then

directed to Drying Plant. Once the coal is dry, it is stored in the warehouse and sorted out later. The heating plant is also located within the Processing Plant. It is intended for the production of heating energy required for the plant itself and Lazarevac municipality. There's also a laboratory that operates within the Plant. It performs wastewater testing and coal quality testing for the Plant and the Republic of Serbia (Elektroprivreda Srbije [EPS], 2021).

4.1.1 Propane

Propane is obtained from natural gas and oil, and it is mixed with other hydrocarbons. Even though it is used as a gas, the propane is stored under high pressure, making it liquified. Compressing a gas into a liquid-like state can be performed at relatively low pressure. Since this gas has no odor, it is being odorized to avoid the hazard of an undetected leak. It undergoes intense combustion while at the same time releasing a great amount of heat. Water vapor and carbon dioxide are recognized as by-products of the combustion process. According to the latest researches, propane is not exhibiting teratogenic, carcinogenic, and mutagenic effects. The most probable pathway of human exposure is by inhalation and direct physical contact. The high concentration of propane in the air can cause rapid breathing, rapid heartbeat, and fatigue, all these due to lower oxygen level (Quality Environmental Professional Associates [QEPA], 2012).

4.2 Above-ground reservoir accident – Case study

The measuring for meteorological data has been performed at the location EPS RB “Kolubara” d.o.o. “Kolubara-Prerada” in the municipality of Lazarevac at 44° 26' 03.3" N latitude and 20° 16' 56.1" E longitude, at an altitude of 150m, on April 18, 2014, at 21:16 (Jelić, 2020).

4.2.1 Stability Class F

The used set of meteorological parameters requires the atmospheric stability of CLASS F (which represents the worst-case scenario) and possesses the following features:

- Wind Speed: 1,5m/s (at 10m from the ground),

- Wind direction: West (W),
- Air Temperature: 10,4 °C,
- Stability Class: F,
- Cloud Cover: 0 tenths,
- Inversion: No Inversion Height,
- Relative Humidity: 98.

A vertical reservoir containing propane is located in the warehouse at EPS RB “Kolubara” d.o.o. “Kolubara-Prerada”. Propane is being stored in the liquid state at ambient temperature.

Geometric data of vertical cylindrical tank:

- Tank Diameter: Ø 58,3m
- Tank Volume: 6m
- Tank Volume: 16.000m³
- Chemical Mass in Tank (Tank is 80% full) = 7,301t
- Circular Opening Diameter: 2,5cm, Opening is 0 centimeters from the tank bottom

Note: Subsidiary “Kolubara-Prerada” did not publish reservoir data, and thus dimensions of the reservoir are provisional, as well as propane info.

4.2.2 Example of Accident at the jet fire

Based on input data of reservoir characteristics, as well as on the entry of the data set of meteorological parameters, followed by the application of the ALOHA program that simulates various accident scenarios, we calculated the following parameters of the accident situation:

- Flame Length: 14m,
- Burn Duration: ALOHA limited the duration to 1h,
- Burn Rate: 434kg/min,
- Total Amount Burned: 26,057kg.

Figure 1 shows the threat zone results for the chosen jet fire scenario by using Google Earth. An accidental propane leak has caused the spreading of the red zone within the radius of 21m. The red zone holds the risk of burns, coma, and possible death within the first 60 seconds. Orange threat zone spreads within the radius of 31m and holds the danger of nausea, collapse, and second-degree burn for everyone exposed. The largest radius is in the yellow zone with a 49m radius. Possible consequences for those within the yellow zone are pain, rapid heartbeat, and vomiting.



Figure 1: Threat zone results for the jet fire scenario.

Source: own.

Thermal radiation from jet fire:

Red: 21m --- (10.0 kW/ (sq m) = potentially lethal within 60s

Orange: 31m --- (5.0 kW/ (sq m) = 2nd degree burns within 60s

Yellow: 49m --- (2.0 kW/ (sq m) = pain within 60s

5 Conclusion

Along with the evolution and modernization of living conditions, disasters have also evolved, causing even more devastating effects. Inadequate land use, urbanization, loss of biotope, and a sudden increase in world population negatively reflected all-natural laws and processes. Human needs greatly exceed Earth's resources, and the planet's reparative systems have begun to collapse. At the same time, new types of disasters are taking global proportions. Environmental disasters have become an

everyday occurrence and, at the same time, a threat to the existence of all living things on this planet.

Extrapolation of historical trends and future predictions show that the chemical industry is not outgrown – furthermore, it helps many industries and modern technologies accelerate technological progress. On the other hand, modern Information and Communications Technologies' development leads to creating new software solutions and computer programs intending to eliminate errors on time simply by applying the appropriate prediction. The goal of the case study presented in this paper is to stress the importance and necessity of having preventive measures.

It must note that safety and prevention systems should not neglect. Instead, we should create a systematic approach to either mitigate or fully eliminate all risks. The change in one's risk perception allows for a timely and appropriate reaction. The prevention of new environmental disasters will ensure the further existence of all species, including humankind, at the same time improving the quality of living.

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