AMMONIA TRANSPORT ACCIDENT EXPOSURE ANALYSIS

Jovana Bondžić[1], Maja Petrović[1]

[1]Department of Environmental Engineering and Occupational Safety and Health, Faculty of Technical Sciences, University of Novi Sad, Trg Dositeja Obradovića 6, Novi Sad, Serbia
e-mail: jovanasimic@uns.ac.rs

Abstract
Anhydrous ammonia proved its efficiency and has been used extensively in the food and processing industry as a refrigerant. Between production and utilization locations it is necessary to organize transport of this substance. Due to its physicochemical properties, there is a possibility for the endangering population and environment in urban areas if the tank traffic accident occurs during the transport. Therefore, this research analyses exposure to ammonia transport accidents through the use of two software applications.

Introduction
Ammonia is, under normal conditions, a colorless gas with a pungent odor [1]. It is lighter than air and soluble in water. In industry, ammonia is used in pure form, without water and is called anhydrous ammonia. It can be liquefied under pressure, or at a temperature below its boiling point. Its boiling point, under atmospheric pressure, is -33,3℃. The low boiling point and the ability to absorb a large amount of heat enable the use of ammonia as a refrigerant. As industrial refrigerant ammonia has been used extensively since chlorofluorocarbons evolved as less toxic refrigerants. Still, it is widely used in industrial refrigeration, because of its low cost and high efficiency. Ammonia is toxic with an 8-hour exposure limit of 25 ml/m^3 and a 15-minute exposure limit of 35 ml/m^3 [2]. The flammable limit of ammonia is between 16-27% by volume [3], while the auto-ignition temperature is 651℃.

In the Republic of Serbia, anhydrous ammonia is produced in HIP Azotara Pančevo, and it is transported to the locations of use by road in tanks. Considering the physicochemical characteristics of ammonia, in the case of an accidental release during transport in populated areas, the human population and environment could be exposed to the toxic and flammable impact of ammonia. In this research, for the exposure analysis of ammonia transport accident, two software ALOHA and Quantum GIS (QGIS) were used. A case study was developed for ammonia release from a tanker truck in the urban area of Novi Sad for three possible hazard scenarios.

Experimental
The quantity of ammonia transported criss-cross the Republic of Serbia differs according to demands, therefore, there is an expectancy of a small tank with ammonia to be driven through the urban area of Novi Sad. Considering the probability of traffic accidents during the transport of ammonia, a location with a high traffic frequency was chosen for the experimental analysis. Based on the ammonia properties, three possible scenarios were identified: dispersion of toxic vapor cloud, ignition of vapor cloud and explosion of the vapor cloud. For the determination of dispersion for each scenario, ALOHA (Areal Locations of Hazardous Atmospheres) software, as a hazard modeling program, was used.

ALOHA is a computer program designed to model chemical releases for emergency responders and planners [4]. It allows user to enter details about a real or potential chemical release, and then it will generate threat zone estimates for various types of hazards such as toxic release dispersion, flammable area of the gas cloud, vapor cloud explosion, BLEVE (Boiling Liquid Expanding Vapor Explosion), jet fire, etc. For the purpose of this research, hazard scenarios were modeled in ALOHA based on input parameters' values listed in Table 1.

Table 1. Input parameters' values for hazard model in ALOHA software

Location, time		Tank parameters		Atmospheric parameters	
Latitude:	45° 14.873' N	Diameter:	1,4 m	Wind speed:	1,1 m/s
Longitude:	19° 50.189' E	Length:	3,6 m	Wind direction:	S
Date:	9.11.2020.	Orientation:	horizontal	Cloud cover:	70 %
Time:	2 p.m.	Mass in the tank:	2500 kg	Air Temperature:	13 °C
		Rupture diameter:	5 cm	Stability class:	E
				Humidity:	86%

The results of the simulation experiments were obtained in the form of graphs showing the threat zones. Threat zones represent the area within which the ground-level exposure exceeds the user-specified level of concern at some time after the beginning of a release [5]. ALOHA will display up to three threat zones, yellow, orange and red, overlaid on a single picture. Using ALOHA's KML export feature, outputs were imported into the Quantum GIS project in order to analyze the overall spatial context of the accident.

Quantum GIS is a user-friendly and open-source Geographic Information System that enables viewing, editing, and analysis of geospatial data. It supports numerous vector, raster, and database formats and functionalities [6]. It is suitable for representing objects from the real system on the spatial model.

Results and discussion

Two of three possible hazard scenarios simulated within the experiment gave results that exceed user-specified levels of concern (LOC). Level of Concern is a threshold value of a hazardous impact (toxicity, flammability, or overpressure) above which a threat to people or property may exist.

For the Toxic Area of Vapor Cloud scenario, Acute Exposure guideline Level (AEGL) was used as a LOC. In Figure 1a, it can be seen that all three LOCs were exceeded in this scenario. In the red zone, it is predicted that the population exposed to more than 1 000 ppm concentration of ammonia could experience life-threatening health effects or death. In the orange zone, people could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape. In the yellow zone, the effects are not disabling and are temporary.

Flammable Area of Vapor Cloud scenario uses 60% of LEL (Lower Explosive Limit) as a LOC for a red zone and 10% of LEL as a LOC for a yellow zone. Both concentrations were exceeded as it is shown in Figure 1b. If there is an ignition source, fire hazard could occur between 90 000 and 15 000 ppm ammonia concentration in the air.

Comparing two graphs it can be noticed that far more area will be endangered in the case of toxic than flammable exposure. In order to analyze the exposed population and property both graphs were imported into the QGIS project (Figure 2). In addition, OpeenStreet Map was used as a base map layer in the project. By visual examination of both scenarios represented within the spatial model, it can be concluded that significant urban areas could be exposed to the hazard of this type. The most vulnerable objects detected in both exposed zones are primary, secondary and higher schools because of high frequency of children presented during the whole day. Also, it should be emphasized that a primary school for children with disabilities will be exposed within the red zone of both scenarios.

a b

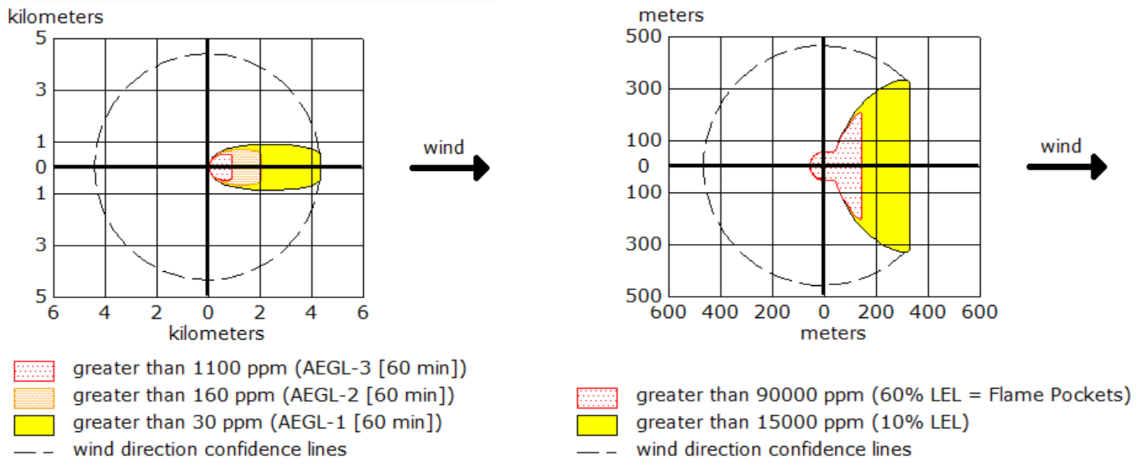

Figure 1. Results obtained by ALOHA software: a – Toxic area; b – Flammable area

a b

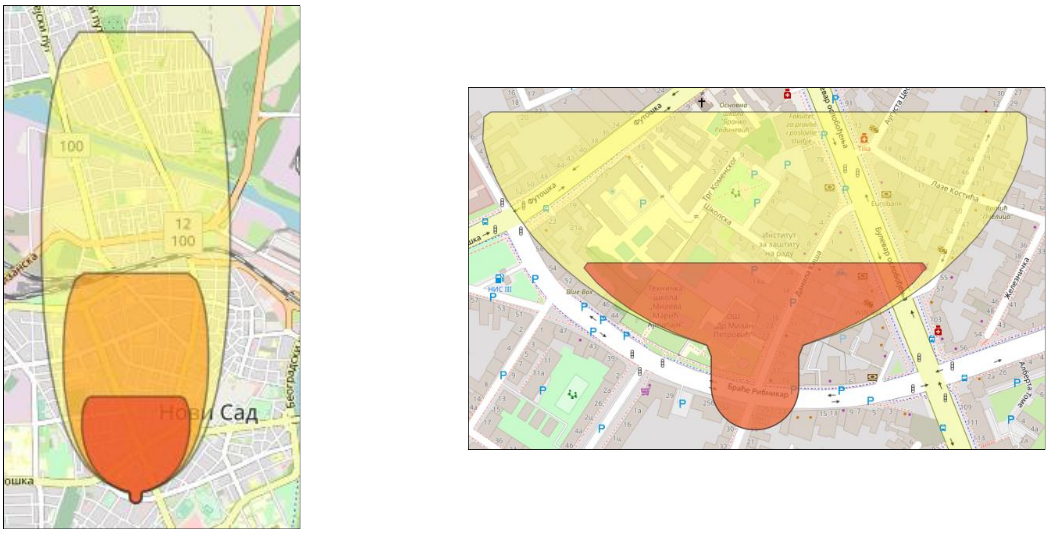

Figure 2. Results imported into QGIS project: a – Toxic area; b – Flammable area

Conclusion

The described method for the analysis of potential accidental situations during the transport of toxic substances enables responders to generate necessary information almost immediately and to conduct appropriate reactions promptly. Therefore, it is extremely important to analyze hazards that could occur in the populated areas in advance, to be as prepared as possible for the unwanted consequences to people and the environment.

References

[1] Janković Z., 2016. Razvoj modela za proračun rizika u logističkim sistemima opasnih materija. PhD thesis. Faculty of Technical Sciences, University of Novi Sad

[2] Eckhoff R., 2016. Explosion Hazards in the Process Industries, Chapter Three - Boiling Liquid Expanding Vapor Explosions (BLEVEs), University of Bergen, Norway

[3] HIP Azotara, 2010. MSDS, Available at: http://hip-azotara.rs/wp-content/uploads /2016/10/amonijak-sr.pdf. (Accessed 10th November 2020)
[4] NOAA, 2020. Available at: https://response.restoration.noaa.gov/sites/default/files/ aloha.pdf (Accessed 11th November 2020)
[5] QGIS, 2020. Available at: https://qgis.org/en/site/about/index.html (Accessed 12th November 2020)
[6] Jones, R., W. Lehr, D. Simecek-Beatty, R. Michael Reynolds. 2013. ALOHA® (Areal Locations of Hazardous Atmospheres) 5.4.4: Technical Documentation. U. S. Dept. of Commerce, NOAA Technical Memorandum NOS OR&R 43. Seattle, WA: Emergency Response Division, NOAA. 96 pp.