8th International HYDROGEN TECHNOLOGIES Congress
12-15 May 2024
Dicle University, Diyarbakır, Türkiye

BİNGÖL ÜNİVERSİTESİ
SAĞLIK BİLİMLERİ FAKÜLTESİ

Evaluation of Hydrogen Transportation by Trucks in terms of Occupational Health and Safety: A Preliminary Hazard Analysis

Mehmet Tunç*, Ramazan Solmaz

Bingöl University, Health Sciences Faculty, Occupational Health and Safety Department, Bingöl, 12000, Türkiye

*E-mail: mtunc@bingol.edu.tr; rsolmaz@bingol.edu.tr; rsolmaz01@gmail.com

I. Introduction

The Joint Research Centre (JRC) of the European Commission released HIAD 2.1 (latest version of The Hydrogen Incident and Accidents Database) in 2023. The data includes hydrogen-related accidents worldwide up to December 2023 (JRC, 2023). Based on this data, 12.8% (97 out of 755) of the accidents occurred during "hydrogen transport and distribution (HTD)".

The transportation of hydrogen gas brings some hazards in terms of occupational health and safety. In order to make the hydrogen ecosystem more given, hazards and risks need to be identified through risk analyses, exposures and vulnerabilities need to be identified and solutions need to be proposed. However, the scientific studies on this topic were not sufficient. Therefore, in this study, the risks that may occur during hydrogen transportation as a representative example is analyzed and some recommendations were proposed.

II. Experimental Set-up and Procedure

Preliminary Hazard Analysis (PreHA) method assesses the impact (severity) and probability (likelihood) of an event to determine risk. Severity, including health, environmental, and economic effects, is evaluated to gauge the event's impact, and it is numbered from 1 (biggest impact) to 4 (lowest impact). Likelihood indicates how frequently the event may occur within a specific timeframe, and a letter is given from the most frequent one to the eliminated one (A, B, C, D and F respectively). Combining severity and likelihood reveals the overall risk level (MIL-STD-882E, 2012).

The paper analyzes 97 accidents associated with HTD, documented in JCR (2023), using the PreHA method. Finally, recommendations are provided for ensuring HTD safety, based on scientific studies.

III. Results and discussions

Hydrogen is transported and distributed via pipelines, ships, and trucks in various forms, including gas, liquid and combinations with substances like ammonia or liquid organic hydrogen carriers (IEA, 2019). In the mentioned document (JRC, 2023), the first accident recorded during HTD occurred in 1970, while the most recent accident was in 2023. While the year with the highest number of accidents was 2013, totaling nine incidents, there were some years where no accidents related to HTD were recorded at all. When examining accidents related to HTD, it is observed that 71% of them involve hydrogen storage in the form of gas or gas mixture, 22% involve liquid, and the remaining 7% are unspecified (JRC, 2023). Looking at the causes of 97 accidents, six main causes are identified. Sometimes one of these alone cause the accident (such as system design error), while other times it is observed that the accident occurs due to two or more causes (27 accidents). The cause of 16 out of 97 accidents is unknown as shown in Fig. 1.

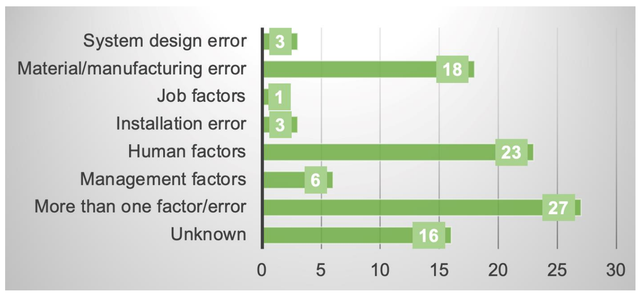

Figure 1. Causes of 97 accidents in numbers (JRC, 2023)

Out of 97 accidents, 72 occurred during transportation by truck. It should be noted that several of these 72 accidents did not happen on the road but during the loading or unloading of hydrogen onto the truck. 16 accidents were related to pipeline distribution, accounting for 17% of the accidents.

The transportation method of 4 accidents could not be determined from the information provided in the document. 2 accidents occurred during transportation by train, and 1 occurred during transportation by sea vessel. Additionally, 2 accidents, classified as "Other," occurred when individuals were transporting hydrogen cylinders with their personal vehicles for private use (JRC, 2023). According to the 97 HTD accidents (JRC, 2023), hydrogen accidents were involved in four main HTD methods. Accidents in these transportation methods have six main causes (Fig. 1).

Table 1. PreHA for hydrogen transportation by trucks

No	Transportation Method	Hazards	Causes	Effects	Risk Degree
1	Truck	Gaseous/ Liquid Hydrogen	According to JRC (2023) stats, there are six main causes: **1. Management factors** - Poor management/maintenance - Insufficient information to employees - Inadequate supervision - Long working hours, insufficient rest periods - Lack of communication - Lack of emergency plans - Work organization and management **2. Human factors** - Carelessness - Inadequate training - Competence - Fatigue and Stress - Use of Appropriate Personal Protective Equipment - Lack of motivation - Ability to make the right decision in emergency situations **3. Installation error** - Wrong placement - Wrong connections - Use of unsuitable materials in connections - Improper installation connections **4. Job factors** - Loading and Unloading Location Selection - Unsuitable tanker selection - Filling and unloading operations - Lack or misuse of safety equipment - Inadequate equipment **5. Material/manufacturing error** - Low quality material production, Poor material selection, etc. - Structural defects of tankers - Source errors - Inadequate protective materials (e.g. coatings) **6. System design error** - Inappropriate design - Use of inappropriate materials - Inadequate pressure and tightness tests - Emergency evacuation system problems - Fire prevention and extinguishing systems - Errors in the design of loading/unloading operations	Fire, Explosion, Frostbite, Asphyxiation, Hydrogen leakage	1B
2		Ammonia		Chemical exposure, Strong alkaline chemical respiration, Poisoning, Fire and explosion, Environmental pollution, Chemical burns	1B
3		Traffic		Traffic accident, Fire, explosion, Hydrogen leakage	1B
4		Roads		Traffic accident	1A
5		Untrained Driver		Traffic accident, Improper intervention in case of emergency etc.	1D
6		Lack of Signs on Truck		Traffic accidents, Improper emergency response etc.	2D

III. Conclusion

Trucks utilised for the transportation of hydrogen face a multitude of risks inherent to heavy-duty vehicles, including traffic accidents, rollovers, and collisions, which can lead to potentially hazardous hydrogen leaks, fires, or explosions. Both gaseous and liquid hydrogen present distinct risks, with gaseous hydrogen being highly flammable and prone to leakage, while liquid hydrogen's extreme cold temperatures pose challenges related to pressure management. Furthermore, the transportation of hazardous materials, such as hydrogen, increases the risk of traffic accidents on roads, particularly in congested urban areas. This risk is further compounded by the variable conditions of road infrastructure. In order to mitigate these hazards, it is imperative to implement rigorous safety protocols, ensure proper training for drivers, adhere to maintenance procedures, and comply with regulatory standards. Furthermore, it is of paramount importance to emphasise the significance of clearly identifying hazardous cargo through the use of appropriate signage. This not only assists emergency responders in their endeavours but also serves to enhance public awareness and promote road safety. Finally, it is of the utmost importance that during the transportation of hydrogen by trucks on roads, both national and international standards and regulations are adhered to. These encompass various aspects, including but not limited to, transportation, storage, and use of hydrogen.

Acknowledgements

The authors are greatly thankful to Bingöl University, Health Sciences Faculty, Occupational Health and Safety Department for supporting this study.

References

Flusberg M. 2023, The challenges of hydrogen transport – and of using hydrogen for transport. https://www.linkedin.com/pulse/challenges-hydrogen-transport-using-martin-flusberg-vc4zf, (Accessed: (May 6, 2024

JRC (Joint Research Centre), 2023, The hydrogen incident and accidents database 2.1 (HIAD 2.1), https://minerva.jrc.ec.europa.eu/en/shorturl/capri/hiadpt, (Accessed: 26.04.2024)

IEA (International Energy Agency), 2019, The Future of Hydrogen 203. International Energy Agency, Paris, pp 18, https://iea.blob.core.windows.net/assets/9e3a3493-b9a6-4b7d-b499-7ca48e357561/The_Future_of_Hydrogen.pdf, (Accessed April 26, 2024)

MIL-STD-882E, 2012, Department of defense standard practice system safety, MIL- STD-882e. Retrieved from http://everyspec.com/MIL-STD/MIL-STD-0800-0899/ MIL-STD-882E_41682/, (Accessed: October 31, 2022)