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# CHEMICAL FIRE AND EXPLOSION HAZARDS AT SEAPORTS: A REVIEW OF HUMAN – CAUSES, CONSEQUENCES AND PREVENTION STRATEGIES

**Ngo Van Nam, Nguyen Huu Hieu, Phan Anh**

*Purpose*. Seaports serve as critical centers for global trade and transportation; however, they are also prone to significant risks of chemical fire and explosion accidents. The purpose of this paper is to examine the human-related causes, consequences, and prevention strategies associated with these hazards at seaports, while addressing their potential to cause severe casualties, environmental harm, economic losses, and social disruption.

*Methods*. This study is based on an analysis of major historical and recent incidents of chemical fires and explosions at seaports. Through this review, the paper evaluates the contributing human factors, the resulting impacts, and the strategies employed to mitigate such risks, while also exploring challenges and opportunities for enhancing safety management of hazardous chemicals.

*Findings*. The findings highlight that chemical fire and explosion accidents at seaports lead to significant consequences, including loss of life, environmental damage, and economic and social setbacks. The paper identifies key prevention strategies and discusses the need for improved safety management practices. In conclusion the recommendations for future research and practical measures to strengthen the handling and safety of hazardous chemicals at seaports are offered.

*Application field of research.* Safety management of hazardous chemicals in seaports.

*Keywords:* chemical fire, chemical explosion, seaport, hazard, risk, prevention, Human Factor Analysis and Classification System (HFACS).

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## 1. Introduction

Seaports are complex systems that involve various activities, such as loading, unloading, storage, handling, and transportation of cargoes, especially hazardous chemicals. According to the International Maritime Organization (IMO), hazardous chemicals are substances that are flammable, explosive, toxic, corrosive, or reactive, and may pose a threat to human health, safety, property, or the environment [1]. The global trade of hazardous chemicals has increased significantly in recent years, due to the growing demand for energy, raw materials, and consumer products. According to the United Nations Conference on Trade and Development (UNCTAD), the volume of hazardous chemicals transported by sea reached 3.1 billion tons in 2019, accounting for 11.4% of the total seaborne trade [2]. However, the increasing trade and handling of hazardous chemicals also increase the potential for chemical fire and explosion accidents at seaports. Chemical fire and explosion accidents are defined as unplanned or uncontrolled events that involve the ignition, combustion, detonation, or deflagration of hazardous chemicals, resulting in heat, flame, pressure, shock wave, sound, or gas release [3; 4]. These accidents can have devastating effects on human lives, health, property, environment, and society. For example, the Tianjin Port fire and explosion accident in China in 2015 killed 165 people, injured 798 people, and caused direct economic losses of 6.87 billion yuan [5]. The Beirut Port explosion in Lebanon in 2020 killed more than 200 people, injured more than 6000 people, and displaced more than 300,000 people [6]. In these accidents, human factors are often considered the main cause of the incident. Therefore, it is essential to understand the human-causes, consequences, and prevention strategies of chemical fire and explosion hazards at seaports, and to improve the safety management of hazardous chemicals at seaports. This paper aims to provide a comprehensive review of the literature on this topic, and to identify the gaps and challenges for future research and practice. The paper is organized as follows: Section 2 analyzes the human-causes of chemical fire

and explosion accidents at seaports, based on the application of the Human Factor Analysis and Classification System model (HFACS model). Section 3 summarizes the main consequences of chemical fire and explosion accidents at seaports, in terms of human, environmental, economic, and social impacts. Section 4 discusses the prevention strategies for improving the safety management of hazardous chemicals at seaports.

## 2. Human-causes of chemical fire and explosion accidents at seaports

Chemical fire and explosion accidents at seaports are complex and dynamic events that involve multiple factors and interactions at different levels of the seaport system. To identify and analyze the causes of these accidents, it is necessary to adopt a system-based approach that considers the seaport system as a whole, rather than focusing on individual components or events. A system-based approach can reveal the underlying causes and mechanisms of accidents, and provide a holistic view of the safety performance and resilience of the seaport system. In this section, we apply a system-based accident model, namely, the Human Factor Analysis and Classification System model (HFACS model), to analyze the causes of chemical fire and explosion accidents at seaports. This model is selected because it is widely used and recognized in the literature, and it has many strengths in terms of the emphasis, structure, classification, and representation of the accident causes [7]. We use the Tianjin Port fire and explosion accident as a case study to illustrate the application of this model.

HFACS model is a taxonomy of human error that was originally developed for aviation accidents, and later adapted for other domains, including maritime accidents [8]. HFACS classifies the human error into four levels: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences. Each level has several subcategories that describe the specific types of human error. Figure 1 shows the HFACS framework and the subcategories.

Lin Zhou et al. applied HFACS to the Tianjin Port fire and explosion accident, they applied HFACS to the Tianjin Port fire accident, and they identified human errors at each of the following levels [9]:

– *Unsafe acts:* The direct cause of the accident was the improper handling of calcium carbide by the Ruihai workers, who used water to cool down the overheated containers, which triggered a chemical reaction that produced acetylene gas, which ignited and exploded [10]. In addition, containers containing nitrocellulose and ammonium nitrate caught fire and exploded, which is also believed to have led to the severity of this explosion [11]. This was an example of skill-based error, which is a failure of attention or technique during the execution of a routine task. Another example of skill-based error was the failure of the firefighters to identify the hazardous chemicals and to use appropriate firefighting methods, which exacerbated the fire and explosion. This was also related to the violation of safety rules by the firefighters, who did not follow the standard operating procedures and did not wait for the arrival of the chemical experts. Moreover, the Ruihai managers committed decision errors, which are failures of judgment or reasoning during the planning or evaluation of a task. For instance, they decided to store and handle hazardous chemicals without proper licenses, permits, or safety measures, and they did not report the accident to the authorities or evacuate the personnel in time.

– *Preconditions for unsafe acts:* The preconditions for unsafe acts are the environmental, personal, and technological factors that affect the performance of the human operators. In the Tianjin Port accident, the environmental factors included the high temperature, humidity, and wind speed, which increased the risk of chemical reaction, ignition, and propagation of the fire and explosion [12]. The personal factors included the lack of knowledge, training, experience, and awareness of the Ruihai workers and the firefighters, who did not recognize the hazards and risks of the chemicals, and did not know how to handle and respond to them. The technological factors included the inadequate design, maintenance, and protection of the containers, warehouses, and vehicles that stored and transported the chemicals, which increased the likelihood of leakage, corrosion, and damage of the chemicals.

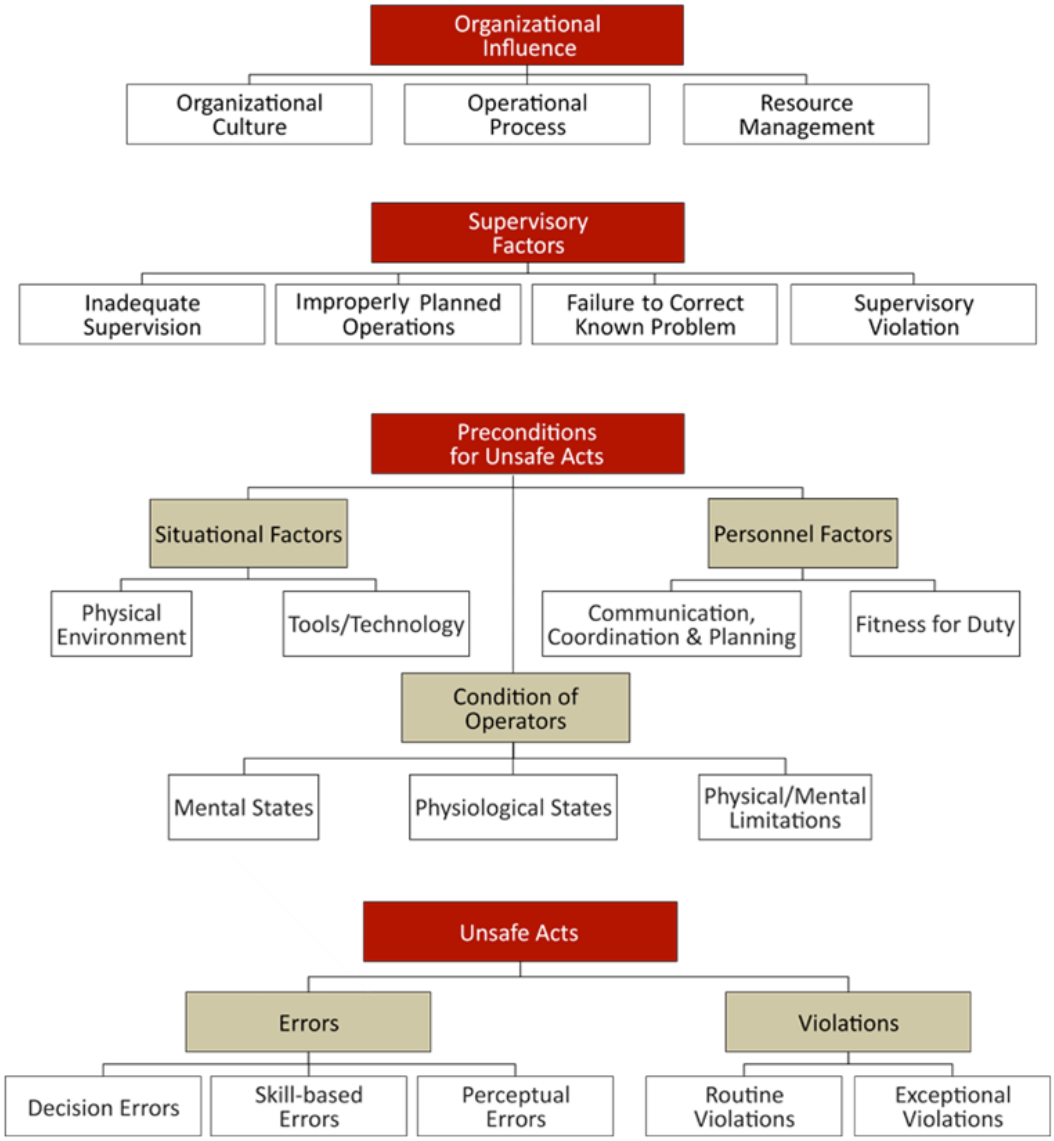


**Figure 1: HFACS framework and subcategories**

– *Unsafe supervision:* The unsafe supervision refers to the failures of the supervisors or managers to provide adequate guidance, oversight, feedback, or support to the human operators. In the Tianjin Port accident, the unsafe supervision included the inadequate supervision of the Ruihai managers, who did not enforce the safety rules and regulations, did not conduct regular inspections and audits, did not provide sufficient training and education, and did not establish effective communication and coordination with the workers, the firefighters, and the authorities [13]. The unsafe supervision also included the negligence of the port authorities, who did not monitor and control the activities and operations of the Ruihai company, did not verify and inspect the licenses and permits of the Ruihai company, did not detect and correct the violations and non-compliances in the activity of the Ruihai company, and did not supervise and assist the emergency response and rescue of the accident.

– *Organizational influences:* The organizational influences are the policies, procedures, culture, and structure of the organization that affect the behavior and performance of the human operators. In the Tianjin Port accident, the organizational influences included the lack of clear and consistent policies and procedures for the management of hazardous chemicals at seaports, which created confusion and inconsistency among the different stakeholders, such as the Ruihai company, the port authorities, the firefighting department, and the environmental protection agency [13]. The

organizational influences also included the poor safety culture and structure of the Ruihai company, which prioritized profit over safety, tolerated violations and non-compliances, and lacked accountability and transparency.

The HFACS analysis can help to identify and classify the human errors that contributed to the accident, and to reveal the causal relationships and interactions among the different levels of human error. However, the HFACS analysis also has some limitations, such as the difficulty of applying the predefined categories to complex and dynamic situations, the lack of consideration of the physical and technical aspects of the system, and the lack of graphical representation of the accident causation [8; 9; 13]. Therefore, to have a more general view of the cause of the incident, it is necessary to consider non-human factors as well, however, in this article, we will only consider subjective factors related to human beings, who is considered the cause of the incident at Tianjin port and other seaports in general.

## 3. The main consequences of chemical fire and explosion accidents at seaports, in terms of human, environmental, economic, and social impacts

A chemical incident often has many consequences for people, the environment and the economy, especially if the chemical incident occurs at seaports. This has been proven through statistics on damage in incidents that occurred at Tianjin port - China and Beirut port - Lebanon. These consequences are summarized below:

**3.1. Human Impacts.** The human impacts of chemical fire and explosion accidents at seaports include the following aspects:

*Fatalities and injuries:* The most direct and obvious impact of chemical fire and explosion accidents at seaports is the loss of human lives and the physical harm to the survivors. The severity of the injuries depends on the type, amount and location of the hazardous materials involved, the intensity and duration of the fire and explosion, the distance and exposure of the victims, and the availability and effectiveness of the emergency response and medical care. The injuries may range from minor burns and cuts to severe trauma, organ damage, and poisoning. Some of the injuries may have long-term or permanent effects, such as disability, chronic pain, and psychological distress [13].

*Health risks:* The health risks of chemical fire and explosion accidents at seaports are mainly caused by the inhalation, ingestion or contact with the toxic substances and pollutants released during and after the accidents. These substances and pollutants may include particulated matter, carbon monoxide, nitrogen oxides, sulfur dioxide, volatile organic compounds, heavy metals, dioxins, furans, and cyanides. The health effects may vary depending on the nature, concentration and duration of the exposure, as well as the susceptibility and health status of the exposed population. The health effects may include respiratory irritation, asthma, bronchitis, pneumonia, cardiovascular diseases, cancer, neurological disorders, reproductive problems, and genetic mutations [13].

*Psychological impacts*: The psychological impacts of chemical fire and explosion accidents at seaports are related to the emotional and mental reactions of the affected individuals and communities. The psychological impacts may include fear, anxiety, stress, depression, post-traumatic stress disorder, grief, anger, guilt, and loss of trust. The psychological impacts may affect the well-being, behavior, and social functioning of the affected individuals and communities, and may require long-term counseling and support [13].

**3.2. Environmental Impacts.** The environmental impacts of chemical fire and explosion accidents at seaports include the following aspects:

*Air pollution:* The air pollution of chemical fire and explosion accidents at seaports is caused by the emission of smoke, dust, and gases from the fire and explosion, as well as the dispersion and deposition of the toxic substances and pollutants in the atmosphere. The air pollution may affect the local and regional air quality, and may contribute to the global climate change. The air pollution may also pose health risks to the exposed population and wildlife, and may damage the vegetation and crops [14; 15].

*Water pollution:* The water pollution of chemical fire and explosion accidents at seaports is caused by the runoff, leaching, and infiltration of the toxic substances and pollutants from the fire and explosion site into the surface water and groundwater. The water pollution may affect the quality and availability of the water resources, and may contaminate the aquatic ecosystems and the food chain. The water pollution may also pose health risks to the exposed population and wildlife, and may damage the aquatic biodiversity and productivity [14; 15].

*Soil pollution:* The soil pollution of chemical fire and explosion accidents at seaports is caused by the deposition, accumulation, and penetration of the toxic substances and pollutants from the fire and explosion site into the soil. The soil pollution may affect the quality and fertility of the soil, and may contaminate the terrestrial ecosystems and the food chain. The soil pollution may also pose health risks to the exposed population and wildlife, and may damage the terrestrial biodiversity and productivity [14; 15].

*Waste generation:* The waste generation of chemical fire and explosion accidents at seaports is caused by the destruction and demolition of the buildings, vehicles, containers, and other materials involved in the fire and explosion. The waste generation may increase the volume and complexity of the solid waste, and may require special handling and disposal due to the presence of hazardous substances and pollutants. The waste generation may also pose health and environmental risks during the collection, transportation, and disposal of the waste [14; 15].

**3.3. Economic Impacts.** The economic impacts of chemical fire and explosion accidents at seaports include the following aspects:

*Property damage:* The property damage of chemical fire and explosion accidents at seaports is caused by the physical destruction and contamination of the buildings, vehicles, containers, and other materials involved in the fire and explosion. The property damage may result in direct losses and costs for the owners, operators, insurers, and users of the property, and may affect the functionality and value of the property [16].

*Business interruption:* The business interruption of chemical fire and explosion accidents at seaports is caused by the disruption and delay of the operations and activities of the seaports and the related industries and sectors. The business interruption may result in indirect losses and costs for the seaports and the related industries and sectors, and may affect the supply chain, trade, and competitiveness of the economy [16].

*Recovery and restoration:* The recovery and restoration of chemical fire and explosion accidents at seaports is caused by the need and demand for the emergency response, rescue, relief, cleanup, remediation, reconstruction, and compensation of the fire and explosion site and the affected areas. The recovery and restoration may result in additional costs and expenditures for the government, the seaports, the related industries and sectors, and the affected population and communities, and may affect the budget, allocation, and distribution of the public and private resources [16].

**3.4. Social Impacts.** The social impacts of chemical fire and explosion accidents at seaports include the following aspects:

*Displacement and relocation:* The displacement and relocation of chemical fire and explosion accidents at seaports is caused by the need and desire for the evacuation, resettlement, and migration of the affected population and communities from the fire and explosion site and the affected areas. The displacement and relocation may result in the loss of home, livelihood, and social network for the affected population and communities, and may affect the demographic, cultural, and political composition of the society [17; 18].

*Social unrest and conflict:* The social unrest and conflict of chemical fire and explosion accidents at seaports is caused by the dissatisfaction, frustration, and anger of the affected population and communities towards the government, the seaports, the related industries and sectors, and the other stakeholders involved in the fire and explosion. The social unrest and conflict may result in the protest, demonstration, violence, and litigation of the affected population and communities, and may affect the stability, security, and justice of the society [17; 18].

*Social cohesion and solidarity:* The social cohesion and solidarity in the event of chemical fire and explosion accidents at seaports is caused by the sympathy, support, and cooperation of the unaffected population and communities towards the affected population and communities. The social cohesion and solidarity may result in the donation, volunteer, and assistance of the unaffected population and communities, and may enhance the resilience, recovery, and harmony of the society [17; 18].

**4. The prevention strategies for improving the safety management of hazardous chemicals at seaports**

The management of hazardous chemicals at seaports involves a complex system of actors, activities, and regulations, such as shippers, carriers, port authorities, terminal operators, customs, emergency responders, environmental agencies, and international conventions. The main challenges for ensuring the safety of hazardous chemicals at seaports include: the diversity and volume of hazardous chemicals handled at seaports, which require adequate identification, classification, labeling, packaging, documentation, and segregation; the potential for accidents, spills, leaks, fires, explosions, or terrorist attacks involving hazardous chemicals, which can result in serious consequences for human health, the environment, and the economy; the lack of awareness, training, and coordination among the different stakeholders involved in the management of hazardous chemicals at seaports, which can lead to errors, violations, or gaps in the implementation of safety measures.

To address these challenges, the following prevention strategies are recommended for improving the safety management of hazardous chemicals at seaports:

– Adopting and enforcing a comprehensive and dynamic web-based management information system (MIS) for hazardous chemicals, which can provide real-time data on the types, quantities, locations, and movements of hazardous chemicals at seaports, as well as facilitate the exchange of information and communication among the relevant parties [19].

– Implementing the OECD Guiding Principles for Chemical Accident Prevention, Preparedness and Response, which set out general guidance for the safe planning and operation of facilities where there are hazardous substances, as well as the mitigation of adverse effects through effective emergency preparedness, land-use planning, and accident response [20].

– Promoting the use of environmentally preferable purchasing policies and periodic chemical inventories to reduce the amount and variety of hazardous chemicals handled at seaports, as well as to identify and eliminate obsolete, unwanted, or banned chemicals [21].

– Providing regular and adequate training for all personnel involved in the management of hazardous chemicals at seaports, covering topics such as chemical hazards, safety data sheets, personal protective equipment, emergency procedures, and waste disposal [22].

– Enhancing the cooperation and coordination among the different stakeholders involved in the management of hazardous chemicals at seaports, through the establishment of joint committees, working groups, or networks, as well as the organization of drills, exercises, or audits.

By implementing these prevention strategies, the safety management of hazardous chemicals at seaports can be improved, thereby protecting human health and the environment, as well as ensuring the smooth and efficient operation of seaports.

**5. Conclusions and recommendation**

Seaports are essential to global trade and transportation, but they also face significant risks of chemical fire and explosion hazards due to the handling and storage of toxic chemicals. These hazards may be caused by human factors, such as errors, negligence, violations or vandalism, or by natural factors, such as earthquakes, storms or lightning. The consequences of the risk of chemical fires and explosions at seaports can be devastating for human health, the environment and the economy as they can lead to casualties, environmental pollution, economic losses and impacts negative to society. To prevent or minimize these dangers, some recommendations are given as follows.

– Implementing a comprehensive and dynamic web-based management information system (MIS) for hazardous chemicals that can provide real-time data and facilitate communication and communication. communication between relevant parties.

– Applying the OECD Guiding Principles on preventing, preparing and responding to chemical accidents, which provide general guidance on the planning and safe operation of facilities with hazardous chemicals, as well as minimize adverse impacts through effective emergency preparedness, land use planning, and accident response.

– Reducing the quantity and type of hazardous chemicals handled at seaports by adopting environmentally friendly purchasing policies and periodic chemical inventories as well as identifying and eliminating obsolete chemicals, unwanted or prohibited.

– Regular and complete training for all staff involved in the management of hazardous chemicals at seaports, including topics such as chemical hazards, safety data sheets, personal protective equipment, regulations emergency procedures and waste treatment.

– Enhancing cooperation and coordination between relevant parties in the management of toxic chemicals at seaports through the establishment of joint committees and working groups.

## REFERENCES


1. Galieriková A., Dávid A., Materna M., Mako P. Study of maritime accidents with hazardous substances involved: comparison of HNS and oil behaviours in marine environment. *Transportation Research Procedia*, 2021. Vol. 55. Pp. 1050–1064. DOI: 10.1016/j.trpro.2021.07.182.
2. *Review of Maritime Transport*: United Nations Conference on Trade and Development (UNCTAD). United Nations, Geneva, 2019. 132 p. ISBN 978-92-1-112958-8.
3. Tang X., Dziemińska E., Koichi Hayashi A., Tsuboi N. Numerical investigation of three deflagration-to-detonation transition conditions related to the velocity of the spontaneous reaction wave. *International Journal of Hydrogen Energy*, 2021. Vol. 46, No. 75. Pp. 37487–37501. DOI: 10.1016/j.ijhydene.2021.09.055.
4. Shijie L. Combustion, Reactive Hazard, and Bioprocess Safety. *Bioprocess Engineering: Kinetics, Sustainability, and Reactor Design*, 2017. Chapter 18. Pp. 1059–1128. DOI: 10.1016/b978-0-444-63783-3.00018-6.
5. Zhang Y., Guo W., Sun C., Jing L. Systems-based Analysis of China-Tianjin Port Fire and Explosion. *Ekoloji*, 2019. Vol. 28, No. 107. Pp. 1921–1928. Available at: https://www.researchgate.net/publication/336413178_Systems-based_Analysis_on_the_China-Tianjin_Port_Fire_and_Explosion (accessed: January 15, 2024).
6. El Zahran T., Geha M., Sakr F., Bachir R., El Sayed M. The Beirut Port Blast: spectrum of injuries and clinical outcomes at a large tertiary care center in Beirut, Lebanon. *European Journal of Trauma and Emergency Surgery*, 2022. Vol. 48. Pp. 4919–4926. DOI: 10.1007/s00068-022-02023-9.
7. Lower M. Magott J., Skorupski J. A System-Theoretic Accident Model and Process with Human Factors Analysis and Classification System taxonomy. *Safety Science*, 2018. Vol. 110. Pp. 393–410. DOI: 10.1016/j.ssci.2018.04.015.
8. Happell S., Wiegmann D. Applying reason: The human factors analysis and classification system (HFACS). *Human Factors and Aerospace Safety*, 2001. Vol. 1. Pp. 59–86.
9. Zhou L., Fu G., Xue Y. Human and organizational factors in Chinese hazardous chemical accidents: A case study of '8.12'Tianjin Port fire and explosion using the HFACS-HC. *International Journal of Occupational Safety and Ergonomics*, 2017. Vol. 24, No. 3. Pp. 329–340. DOI: 10.1080/10803548.2017.1372943.
10. *Tianjin explosions: warehouse 'handled toxic chemicals without licence' – reports*. Available at: https://www.theguardian.com/world/2015/aug/18/tianjin-blasts-warehouse-handled-toxic-chemicals-without-licence-reports (accessed: August 18, 2024).
11. Fu G., Wang J., Yan M. Anatomy of Tianjin Port fire and Explosion: Process and Causes. *Process Safety Progress*, 2016. Vol. 35, No. 3. Pp. 216–220. DOI: 10.1002/prs.11837.
12. Chen Q., Wood M., Zhao J. Case study of the Tianjin accident: Application of barrier and systems analysis to understand challenges to industry loss prevention in emerging economies. *Process Safety and Environmental Protection*, 2019. Vol. 131. Pp. 178–188. DOI: 10.1016/j.psep.2019.08.028.

13. Zhang Y., Jing L., Sun C. Systems-Based Analysis of China-Tianjin Port Fire and Explosion: A Comparison of HFACS, AcciMap, and STAMP. *Journal of Failure Analysis and Prevention*, 2018. Vol. 18. Pp. 1386–1400. DOI: 10.1007/s11668-018-0534-1.
14. Martin D., Tomida M., Meacham B. Environmental impact of fire. *Fire Science Reviews*, 2016. Vol. 5. Article 5. 21 p. DOI: 10.1186/s40038-016-0014-1.
15. Small R.D. Environmental impact of fires in Kuwait. *Nature*, 1991. Vol. 350. Pp. 11–12. DOI: 10.1038/350011a0.
16. Kajitani Y., Cruz A.M., Tatano H., Nakano K., Choi J., Yasuda N. Economic impacts caused by the failure of a maritime global critical infrastructure: the case of the Malacca and Singapore Straits. *Journal of Transportation Security*, 2013. Vol. 6. Pp. 289–313. DOI: 10.1007/s12198-013-0117-z.
17. Barnes G., Baxter J., Litva A., Staples B. The social and psychological impact of the chemical contamination incident in Weston Village, UK: a qualitative analysis. *Social Science & Medicine*, 2002. Vol. 55, No. 12. Pp. 2227–2241. DOI: 10.1016/S0277-9536(01)00367-7.
18. Rábade J., Aragoneses C. Social Impact of Large-Scale Forest Fires. *Proc. of the Second International Symposium on Fire Economics, Planning, and Policy: A Global View, Albany, California, April, 2008*. United States Department of Agriculture, Forest Service, Pacific Southwest Research Station. Ed. by: A. González-Cabán. Albany, 2008. Pp. 23–33.
19. Ramamurthy A. Mongolia: Improving the Management of Hazardous Chemicals. *Asian Development Bank. Philippines*, 2019. Available at: https://coilink.org/20.500.12592/fn5gxv (accessed: January 15, 2024). CID: 20.500.12592/fn5gxv.
20. OECD *Guiding Principles for Chemical Accident Prevention, Preparedness and Response*: Guidance for Industry (including Management and Labour), Public Authorities, Communities, and other Stakeholders. Paris: OECD Publishing, 2003. 190 p. (OECD Environment, Health and Safety Publications. Series on Chemical Accidents, No. 10). DOI: 10.1787/9789264101821-en.
21. *A flexible framework for addressing chemical accident prevention and preparedness*: A Guidance Document. United Nations Environment Programme, 2010. 188 p. ISBN: 978-92-807-3094-4.
22. *Your steps to chemical safety: A guide for small business*. Health and Safety Authority, 2011. 36 p. ISBN: 978-1-84496-147-4.

# Chemical fire and explosion hazards at seaports: a review of human – causes, consequences and prevention strategies

# Опасности химических пожаров и взрывов в морских портах: обзор человеческих факторов, последствий и стратегий предотвращения

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# ОПАСНОСТИ ХИМИЧЕСКИХ ПОЖАРОВ И ВЗРЫВОВ В МОРСКИХ ПОРТАХ: ОБЗОР ЧЕЛОВЕЧЕСКИХ ФАКТОРОВ, ПОСЛЕДСТВИЙ И СТРАТЕГИЙ ПРЕДОТВРАЩЕНИЯ

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*Цель.* Морские порты являются важнейшими центрами мировой торговли и транспортировки, однако они подвержены значительным рискам химических пожаров и взрывов. Целью данной статьи является изучение человеческих факторов, последствий и стратегий предотвращения, связанных с этими опасностями в морских портах, а также рассмотрение их потенциала вызывать серьезные жертвы, вред окружающей среде, экономические потери и социальные потрясения.

*Методы.* Это исследование основано на анализе крупных исторических и недавних инцидентов с химическими пожарами и взрывами в морских портах. Оцениваются способствующие этому человеческие факторы, последствия и стратегии, применяемые для снижения таких рисков, а также изучаются проблемы и возможности для повышения безопасности управления опасными химическими веществами.

*Результаты.* Результаты исследования подчеркивают, что химические пожары и взрывы в морских портах приводят к значительным последствиям, включая гибель людей, ущерб окружающей среде, а также к экономическим и социальным проблемам. В работе определяются основные стратегии профилактики и обсуждается необходимость улучшения методов управления безопасностью. В заключение предлагаются рекомендации по проведению будущих исследований и практических мер по повышению эффективности обращения и безопасности опасных химических веществ в морских портах.

*Область применения исследований.* Управление безопасностью опасных химических веществ в морских портах.

*Ключевые слова*: химический пожар, химический взрыв, морской порт, опасность, риск, предотвращение, система анализа и классификации человеческого фактора.

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## ЛИТЕРАТУРА

1. Galieriková, A. Study of maritime accidents with hazardous substances involved: comparison of HNS and oil behaviours in marine environment / A. Galieriková, A. Dávid, M. Materna, P. Mako // Transportation Research Procedia. – 2021. – Vol. 55. – P. 1050–1064. – DOI: 10.1016/j.trpro.2021.07.182.
2. Review of Maritime Transport 2019: United Nations Conference on Trade and Development (UNCTAD). – United Nations, Geneva, 2019. – 132 p. – ISBN 978-92-1-112958-8.
3. Tang, X. Numerical investigation of three deflagration-to-detonation transition conditions related to the velocity of the spontaneous reaction wave / X. Tang, E. Dziemińska, A. Koichi Hayashi, N. Tsuboi // International Journal of Hydrogen Energy. – 2021. – Vol. 46, № 75. – P. 37487–37501. – DOI: 10.1016/j.ijhydene. 2021.09.055.
4. Shijie, L. Combustion, Reactive Hazard, and Bioprocess Safety / L. Shijie // Bioprocess Engineering: Kinetics, Sustainability, and Reactor Design / L. Shijie. – New York, 2017. – Chapter 18. – P. 1059–1128. – DOI: 10.1016/b978-0-444-63783-3.00018-6.
5. Zhang, Y. Systems-based Analysis on the China-Tianjin Port Fire and Explosion / Y. Zhang, W. Guo, C. Sun, L. Jing // Ekoloji. – 2019. – Vol. 28, № 107. – P. 1921–1928. – URL: https://www.researchgate.net/publication/336413178_Systems-based_Analysis_on_the_China-Tianjin_Port_Fire_and_Explosion (date of access: 15.01.2024).
6. El Zahran, T. The Beirut Port Blast: spectrum of injuries and clinical outcomes at a large tertiary care center in Beirut, Lebanon / T. El Zahran, M. Geha, F. Sakr [et al.] // European Journal of Trauma and Emergency Surgery. – 2022. – Vol. 48. – P. 4919–4926. – DOI: 10.1007/s00068-022-02023-9.
7. Lower, M. A System-Theoretic Accident Model and Process with Human Factors Analysis and Classification System taxonomy / M. Lower, J. Magott, J. Skorupski // Safety Science. – 2018. – Vol. 110. – P. 393–410. – DOI: 10.1016/j.ssci.2018.04.015.

8. Happell, S. Applying reason: The human factors analysis and classification system (HFACS) / S. Happell, D. Wiegmann // Human Factors and Aerospace Safety. – 2001. – Vol. 1. – P. 59–86.
9. Zhou, L. Human and organizational factors in Chinese hazardous chemical accidents: A case study of '8.12'Tianjin Port fire and explosion using the HFACS-HC / L. Zhou, G. Fu, Y. Xue // International Journal of Occupational Safety and Ergonomics. – 2017. – Vol. 24, № 3. – P. 329–340. – DOI: 10.1080/10803548.2017.1372943.
10. Tianjin explosions: warehouse 'handled toxic chemicals without licence' – reports / R. Fergus. – China: The Guardian, 2015. – URL: https://www.theguardian.com/world/2015/aug/18/tianjin-blasts-warehouse-handled-toxic-chemicals-without-licence-reports (date of access: 18.08.2024).
11. Fu, G. Anatomy of Tianjin Port fire and Explosion: Process and Causes / G. Fu, J. Wang, M. Yan // Process Safety Progress. – 2016. – Vol. 35, № 3. – P. 216–220. – DOI: 10.1002/prs.11837.
12. Chen, Q. Case study of the Tianjin accident: Application of barrier and systems analysis to understand challenges to industry loss prevention in emerging economies / Q. Chen, M. Wood, J. Zhao // Process Safety and Environmental Protection. – 2019. – Vol. 131. – P. 178–188. – DOI: 10.1016/j.psep.2019.08.028.
13. Zhang, Y. Systems-Based Analysis of China-Tianjin Port Fire and Explosion: A Comparison of HFACS, AcciMap, and STAMP / Y. Zhang, L. Jing, C. Sun // Journal of Failure Analysis and Prevention. – 2018. – Vol. 18. – P. 1386–1400. – DOI: 10.1007/s11668-018-0534-1.
14. Martin, D. Environmental impact of fire / D. Martin, M. Tomida, B. Meacham // Fire Science Reviews. – 2016. – Vol. 5. – Article 5. – 21 p. – DOI: 10.1186/s40038-016-0014-1.
15. Small, R.D. Environmental impact of fires in Kuwait / R.D. Small // Nature. – 1991. – Vol. 350. – P. 11–12. – DOI: 10.1038/350011a0.
16. Kajitani, Y. Economic impacts caused by the failure of a maritime global critical infrastructure: the case of the Malacca and Singapore Straits / Y. Kajitani, A.M. Cruz, H. Tatano [et al.] // Journal of Transportation Security. – 2013. – Vol. 6. – P. 289–313. – DOI: 10.1007/s12198-013-0117-z.
17. Barnes, G. The social and psychological impact of the chemical contamination incident in Weston Village, UK: a qualitative analysis / G. Barnes, J. Baxter, A. Litva, B. Staples // Social Science & Medicine. – 2002. – Vol. 55, № 12. – P. 2227–2241. – DOI: 10.1016/S0277-9536(01)00367-7.
18. Rábade, J. Social Impact of Large-Scale Forest Fires / J. Rábade, C. Aragoneses // Proc. of the Second International Symposium on Fire Economics, Planning, and Policy: A Global View, Albany, California, April, 2008 / United States Department of Agriculture, Forest Service, Pacific Southwest Research Station: ed. by A. González-Cabán. – Albany, 2008. – P. 23–33.
19. Ramamurthy, A. Mongolia: Improving the Management of Hazardous Chemicals. Asian Development Bank. Philippines, 2019. – URL: https://coilink.org/20.500.12592/fn5gxv (date of access: 15.01.2024). – CID: 20.500.12592/fn5gxv.
20. OECD Guiding Principles for Chemical Accident Prevention, Preparedness and Response: Guidance for Industry (including Management and Labour), Public Authorities, Communities, and other Stakeholders. – Paris: OECD Publishing, 2003. – 190 p. – (OECD Environment, Health and Safety Publications. Series on Chemical Accidents, No. 10). – DOI: 10.1787/9789264101821-en.
21. A flexible framework for addressing chemical accident prevention and preparedness: A Guidance Document / United Nations Environment Programme, 2010. – 188 p. – ISBN: 978-92-807-3094-4.
22. Your steps to chemical safety: A guide for small business / Health and Safety Authority, 2011. – 36 p. – ISBN: 978-1-84496-147-4.