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Research on Safety Risk, Prevention and Control in Port Dangerous Goods Container Yard

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Abstract. Based on the analysis of the storage, safety risks and risk factors of the dangerous cargo container yard in the port, the accident hazards and the scope of impact were evaluated through simulation calculations. The results show that the main risk factors are inherent dangerous characteristics of dangerous goods, improper storage modes, substandard packaging, and the failure to implement the main responsibility of the port operator, the weak safety awareness of employees, the inadequate safety supervision and the improper emergency response. The influence range extends as far as the surrounding regions. It is necessary to take countermeasures such as limiting the stockpile, equipping with safety facilities, and strict management to prevent and control risks and accidents.

Keywords. Cargo container yard, Port, Simulation calculations, Risks and accidents.

1. Introduction

The "8.12 Tianjin Binhai New Area Explosion Accident" killed 165 people and caused direct economic losses of more than 6.8 billion yuan. The accident indicates that enormous potential risks maybe exist during the activities in the port dangerous goods container yard. Relevant research has been carried out in China and around the world to address the risks, prevention and control in port dangerous goods container yard. Fabiano et al. studied port dangerous goods yard management and control measures in the aspects of port dangerous goods yard operators, working machinery and safety protection infrastructures in the yard [1]. Guangyu Lyu analyzed the risks of dangerous goods containers from multiple perspectives, such as the classification of dangerous goods at the port, risk factors in the operation process and control measures [2]. Compared stockpiling methods, direct loading and unloading range with the International Maritime Organization (IMO) Recommendations, Lu et al. put forward some prevention and control measures: decentralized storage, and expanded the range of direct loading and unloading [3]. Due to the large number of dangerous goods storage yards in China's ports, the classifications of the stored dangerous goods, storage conditions and the surrounding environment of the yards are various, and the ways of safety management and supervision are distinctive. It is indispensable to address the special risk characteristics of dangerous goods yards in port. To ensure safe operation of the dangerous goods yards in port, further studies about the risks should be carried out and corresponding prevention and control measures should be provided.

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2. Stockpiling Status of Dangerous Goods Container Yards in Port

With the rapid development of water transportation in China, the volume of container water transportation has shown an increasing trend [4-5]. Up to the end of 2018, the national port container throughput reached 215.5 million twenty-foot equivalent unit (TEU), the total number of port container yards has exceeded 2,300. There are more than 70 dangerous goods container yards, the dangerous goods container throughput is nearly 1.7 million TEU, and the yard operation volume is 1.25 million TEU. In particular, Shanghai's dangerous goods container throughput reached 830 thousand TEU, which is close to 50% of the national dangerous goods container throughput.

In China, dangerous goods storage yards are mainly distributed in the coastal areas and economically developed areas in the middle and lower reaches of the Yangtze River [6]. There are many major hazard sources of dangerous goods at first-class in ports. Some storage yards are built near to sensitive places, such as residential areas or other densely populated regions.

Chinese government implements administrative permission for the operation of dangerous goods storage yard. Under the relative regulations and standards, dangerous goods containers should be stored in special areas for safety purpose. Among them, dangerous goods containers of explosives in class 1.1 and 1.2 and ammonia nitrate should only be allowed transport to or from ships directly in port area. The storage of dangerous goods containers of explosives (except the explosives in class 1.1 and 1.2), gases in class 2, and radioactive materials in class 7 should be limited both on quantities and time by a safety assessment from a qualified intermediary agency and approved by the local port authorities. Therefore, the following types of cargoes can be stored in port: explosives in class 1 (mentioned in class 1.3 and 1.4), gases in class 2, flammable liquids in class 3, flammable solids in class 4, substances liable to spontaneous combustion, and substances that can emit flammable gas in contact with water, oxidizing substances and organic peroxides in class 5, toxic substances and infectious substances in class 6, radioactive articles in class 7, corrosive substances in class 8, miscellaneous dangerous substances and articles (including environmentally hazardous substances) in class 9.

From the above analysis, it can be seen that China's ports have a wide range and a large number of dangerous goods container stockpiles, with many types of stockpiled goods, large stockpiles, complex surrounding environments, and high inherent security risks.

3. Security Risks and Influencing Factors

Dangerous goods have different characteristics and are characterized by flammability, explosiveness, toxicity, corrosiveness, radioactivity, and oxidability [7]. And there exist major accident risks such as explosion, fire, leakage, poisoning, and radiation. In addition, the safety of dangerous goods is also restricted by human, the environment, facilities, and equipment, etc. Besides the above-mentioned basic characteristics of China's port dangerous goods container yards, since the containers are transported from goods packing to the yard, they may have to go through multiple links such as packing, handling, transport, and storage, etc. Problems can occur at each link that affects the integrity of the packaging of the goods, even some goods may have packaging problems when they leave the factory [8]. Due to the influence of these complex factors, potential safety hazards exist objectively, which can easily lead to accidents, and may cause serious casualties, major economic losses and environmental pollution. In particular, some major dangerous goods accidents may have catastrophic consequences, even devastating impact on the whole industry [9]. On August 12, 2015, because of the loss of wetting agent, the nitrocellulose in the container at the south side of arrival area in the dangerous goods warehouse of Tianjin Port Ruihai Company dried locally, which accelerated the decomposition and heat release due to the high temperature (weather) and other factors. On account of accumulated heat and spontaneous combustion, the large-scale burning of nitrocellulose and other dangerous chemicals in the adjacent containers for a long time, which leads to a particularly serious fire and explosion accident. In this accident, 165 people were killed, 798 injured and 7533 containers damaged [10-11].

According to the security characteristics and security risks of port dangerous goods container stacks, the technology and method of safety system engineering and the Accident-Causing Theory were applied. Based on the analysis of five aspects of goods risk, environment risk (including layout and location factors), equipment and facility risk, personnel unsafety and safety management, it was found the main risk causes of the dangerous goods container yard include: inherent dangerous characteristics and stacking quantity of goods kinds, safety distance, safety awareness of employees, responsibility system for production safety, safety supervision regulations and standards, safety regulations and operating rules, dangerous goods packaging, etc.

The inherent dangerous characteristics of dangerous goods are the internal causes of serious accidents such as fire, explosion, leakage, and personnel poisoning. The inherent risk factors cannot be eliminated. In order to maximize profits, some port dangerous goods container storage companies ignore national laws, regulations, and standards, ignore the main responsibility for production safety, ignore the category and quantity restrictions. They store up dangerous goods containers of explosives mentioned in class 1.1 and 1.2 and ammonium nitrate, etc., which severely exceed the design scale and design range. Once an accident occurs, the extent of damage may be out of control.

Considering the operation costs and the requirements of safety management, port operators in China usually store the dangerous goods containers in port in accordance with segregation requirements, but in a relative centralized way, which is a bit different from the international practices. This kind of stockpiling objectively forms the high concentration and superposition of all kinds of accident risks, such as fire, explosion, leakage and toxic and harmful diffusion. Once an accident happens, the consequences will be huge. Moreover, as each type of dangerous goods has its own dangerous characteristics, the physical and chemical characteristics of different types of dangerous goods vary greatly, and the emergency disposal measures after the occurrence of danger also have their own requirements. If there are many types of dangerous goods stored in the container yard, the emergency rescue is bound to be limited.

As far as safety distance is concerned, the safety distance between the port dangerous goods container yard and the relevant production and living facilities, to a certain extent, determines the severity of the consequences caused by accidents. The lack of spacing is prone to cause serious and major safety accidents. The location of port container terminals has historically not been emphasized far from urban areas. With the development of port and city facing each other, the range of port area is becoming more and wider, the scale of city is expanding, and the boundary between them is gradually blurred. Many ports and urban areas are integrated together. Thus, the distance between the dangerous goods container yard and the surrounding sensitive places is insufficient, even some container yard is adjacent or staggered with residential quarters and other densely populated places.

As far as the safety awareness of the employees is concerned, the weak safety awareness of the head, managers and operators of some port dangerous goods container yard enterprises is an important factor leading to accidents. In particular, some main persons in charge have a tendency of "emphasizing benefits and deeming safety", disregarding national production safety laws and regulations and related requirements, and even violating laws and regulations for a long time. Some enterprises have long-term hidden safety hazards, serious lack of safety education and training, and extremely low levels of safety. At the same time, some on-site managers and operators ignore labor discipline and operating procedures. Violations of command, operation and labor discipline are very serious.

As far as the packaging of dangerous goods is concerned, the container packaging of dangerous goods does not conform to the specifications. At present, it is common for dangerous goods containers to be found damaged when they enter the yard or the containers are leaked after entering the yard. This indicates that these dangerous goods are either to be packed unqualified when leaving the factory, or damaged due to rough operation during packing or transportation, or even the above situations may coexist. At the same time, the rough operation of the operators after containers enter the yard can't be ignored. Furthermore, before the dangerous goods container enters the port yard, there may be links such as unpacking, consolidation, and corresponding handling, loading and unloading. If the operation

is not strictly performed in accordance with the operating regulations and the requirements of the characteristics of dangerous goods, it may also leave hidden dangers of accidents.

In terms of emergency disposal, the emergency disposal is not timely and the methods and measures are improper. Many of the major disasters are caused by the failure to deal with the dangerous situations and accidents timely and effectively at the beginning. For the port dangerous goods container yard, the most important thing is to find the fire as soon as possible and put out the fire quickly. As long as the fire is not allowed to spread, there will be no explosion of dangerous goods and the spread of major leakage. Therefore, the yard operation enterprises themselves should play the most principal role in emergency response in the early stage of danger and accident, rather than waiting for professional fire forces to let the fire spread. It is very significant to detect and deal with the danger in time. It is also very significant to understand and accurately judge the extent of harm after the development of the dangerous condition, and to adopt the correct methods and measures. However, under the highly centralized storage mode, the emergency disposal of dangerous goods container yard may be more complicated than that of oil depot and chemical plant.

Based on the above analysis, it can be found that at present, complex operating environment of dangerous goods container yards in domestic ports, inadequate regulations and standards, lack of enterprise management, and inadequate emergency disposal constitute the source of major risk factors. And it is difficult to eliminate these risk factors completely in a short term. So it is necessary to continuously enhance the safety level of dangerous goods container yards by adopting relevant measures and means.

4. Accident Simulation Assessment

At present, the types of dangerous goods in the port container yard cover all categories. From the perspective of the dangerous characteristics of the goods, explosives in class 1 pose the greatest safety risk. This category is selected for accident simulation calculation and evaluation in this paper. Based on the investigation and analysis of actual operations, only a small number of container terminals in China have fireworks and firecrackers (in class 1.3 and 1.4) stockpiling qualifications for limited time and limited quantity, and the licensed operation is "stocking fireworks and firecrackers (in class 1.3) 10 TEU for a limited time of 48 hours." According to the provisions of Chapter 5 of the "Determination method of external safety distance for hazardous chemicals production unit and storage installations " (GB/T37243-2019), the simultaneous explosion in class 1.3 of fireworks and firecrackers with the largest storage capacity of 10 TEU in the yard is taken as the worst accident scenario. Then the total dose of fireworks and firecrackers in class 1.3 of 10 TEU is 5000 kg (calculated by 500 kg per TEU), which is converted into trinitrotoluene (TNT) equivalent of 1800 kg (calculated based on the TNT equivalent of black powder of 0.35). On the basis of the air shock wave overpressure threshold of different types of protection targets, the corresponding external safety protection distance is figured out, as shown in table 1 below:

Protection target (classified according to GB36894)	Air shock wave overpressure threshold (Pa)	External safety protection distance(m)
Class I protection targets among highly sensitive protection targets, important protection targets, and general protection targets	2000	716
Class II protection targets among general protection targets	5000	313
Class III protection targets among general protection targets	9000	193

Table 1. Calculated values of external safety protection distance.

Combined with the topographic map, taking the explosion point as the center, draw the influence range map of different air shock wave overpressure threshold, as shown in figure 1.



Figure 1. Influence range of overpressure threshold of explosive air shock wave.

It can be seen from figure 1 that the air shock wave overpressure threshold of Class II protection targets among general protection targets have affected the surrounding area. The influence range of the air shock wave overpressure threshold of the protection targets of Class III among general protection

targets is as far as 716 m. Therefore, it is necessary to take safety prevention and control measures and limit the storage, so as to effectively control the safety risk of dangerous goods container storage.

5. Safety Risk Prevention and Control

The above research shows that the safety risk of dangerous goods storage yard in port of China has its own characteristics and complexity. It is necessary to take measures like improving the safety management system and safety facilities, adjusting the storage and direct loading and unloading mode of storage yard, strengthening safety and emergency management to control safety risk, reduce and eliminate accidents.

Improve system construction and strengthen management. Formulate design specifications for port dangerous cargo storage yards, and formulate national standards based on the "The safety rules for handing dangerous cargo container in port (JT 397-2007)". Port operating companies should establish dual prevention mechanisms and safety production standardization management system, and effectively implement them to achieve systematic operation and management, and fully implement the main responsibility of enterprise safety production management. Meanwhile, relevant departments should strengthen safety supervision, strict law enforcement, increase penalties for concealment, and increase the cost of violation.

Improve basic safety facilities. Dangerous goods container yard shall be equipped with targeted isolation facilities, fire-fighting facilities, traffic facilities, safety warning systems, sewage collection and anti-seepage facilities, lighting facilities, lightning protection and anti-static facilities, alarm devices, spray cooling facilities, monitoring equipment, emergency treatment facilities, personal safety protection equipment and other safety equipment and facilities according to the type of storage and safety risks, and ensure they are in good condition.

Control the stacking quantity strictly. According to the surrounding environmental and safety conditions of the storage yard, especially the distance to the surrounding protection targets, scientifically evaluate and determine the amount of storage in the storage yard to ensure the safety of surrounding personnel and facilities.

Adjust the direct loading and unloading mode and limited storage. On the grounds of "The safety rules for handing dangerous goods container in port (JT 397-2007)", the range of direct loading and unloading is appropriately expanded to explosives in class 1 (except class 1.4S), infectious substances in class 6.2 and radioactive substances in class 7, and adjust the applicable types of goods with limited time and limited quantity and regulate the time limit of goods.

Adjust the mode of port storage of dangerous goods containers. Adjust the current mode of high concentration of all kinds of dangerous goods in China to the mode of relatively concentration and moderate dispersion according to the categories and physical and chemical characteristics of dangerous goods, i.e. the containers of inflammable and explosive goods and the containers of toxic and harmful goods are stored separately, and other general dangerous goods containers can be stored together with ordinary goods containers.

Enhance the management of packaging damage of dangerous goods. Investigate and study deeply the causes and treatment measures for the damage of dangerous goods packaging. Relevant ministries and commissions jointly shall carry out the safety risk management of dangerous goods packaging damage. Strengthen the safety inspection during the stacking process in the yard, and handle in time when package abnormality or leakage is found.

Improve training methods and enhance training effectiveness. The safety qualities of dangerous goods operators and managers play a vital role in the management and control of safety risks. Seriously carry out training and education on the characteristics and operating procedures of dangerous goods, emergency measures, and analysis of typical accident cases. Operation procedures, accident cases, etc. should be made into live-action demonstration videos or anime loops to be played, and uploaded to the intranet for employees to learn at any time. Carry out regular online test for relevant personnel to enhance the intuitiveness and interest of safety training and improve the training

effect. Continuously improve their safety knowledge, safety skills and safety awareness, and strive to enhance the overall professional quality of the on-site operators of the dangerous goods container yard.

Establish information management system of dangerous goods container. There are many kinds of goods in the container yard of dangerous goods in the port, and the quantity is always in the dynamic change. Establish the dangerous goods container information management system, improve the accuracy and effectiveness of the management of dangerous goods. Grasp the relevant information and changes of dangerous goods in time, observe and analyse the security situation in real time, and share the information with the relevant management departments. Take effective measures in time to prevent accidents when find problems.

Improve emergency response system and enhance practical capability. The emergency management of dangerous goods should focus on the response speed and actual practical ability. Once an accident occurs to dangerous goods, it may cause great damage in a short time. Therefore, the first-time emergency treatment is particularly important, and the response speed and emergency treatment of on-site personnel capacity requirements are also high. In order to advance the emergency response ability of the site personnel, in addition to having a sound emergency response plan, complete emergency materials and equipment, it is also necessary to carry out regular practice drills, start the emergency plan suddenly without preparation, observe the response of the site personnel, and find out the existing problems. Through continuous improvement and practice, to gradually improve the emergency response capacity.

6. Conclusions

There are many dangerous goods container yards in China's ports, with many kinds of stocks, large quantities and complicated surrounding environmental conditions. The stored goods have the characteristics of flammable, explosive, toxic, corrosive, radioactive and oxidative. The main safety risks are leakage, fire, explosion, personnel poisoning, environmental pollution, etc. and may cause personal injury, property loss and environmental ecological disaster. It is mainly due to the inherent hazardous characteristics of the goods and the quantity of storage, the safety distance, the safety awareness of employees, the safety production responsibility system, safety supervision regulations and standards, safety rules and regulations and operating procedures, and the packaging of dangerous goods. Examples of accident simulation assessment show that the impact of the accident extends far to the surrounding areas. Measures such as perfecting the system construction, strengthening the management, improving the basic safety facilities, controlling the storage quantity strictly, adjusting the direct loading/unloading and limited storage, adjusting the storage mode, strengthening the management of dangerous goods packaging damage, improving the training effectiveness, establishing the dangerous goods container information management system, improving the emergency system and enhancing the actual practical capability should be taken to effectively prevent and control the safety risks and accidents.

References

- Chu G and Lyu G 2018 Critical assessment on dangerous goods storage container yard of port: Case study of lpg tank container *IEEE International Conference on Industrial Engineering* and Engineering Management 1751-1755
- [2] Fabiano B, Currò F, Reverberi A P and Pastorino R 2010 Port safety and the container revolution: A statistical study on human factor and occupational accidents over the long period *Safety Science* 48 (8) 980-990.
- [3] Fu G, Wang J and Yan M 2016 Anatomy of Tianjin Port fire and explosion: Process and causes Process Safety Progress 35 (3) 216-220
- [4] Kebedow K G and Oppen J 2019 Including containers with dangerous goods in the cargo mix problem for container vessel stowage *Communications-Scientific letters of the University of Zilina* 21 (2) 100-113

- [5] Li X, Mao F Y and Zhang J C 2017 Container multimodal transport channel in shandong district path evaluation and optimization *3rd Annual International Conference on Management, Economics and Social Development (ICMESD 17)* (Atlantis Press)
- [6] Lu X, Ruan C, Li R, Xie T and Xu H 2019 Comparative study on safe storage of dangerous goods containers in port areas 5th International Conference on Transportation Information and Safety (ICTIS) (IEEE) 608-610
- [7] Lv G Y 2018 Risk prevention and control of dangerous goods container in port *Supervision of Chemicals* **5** 90-92 (in Chinese)
- [8] Wang L, Notteboom T, Lau Y Y and Ng A K 2017 Functional differentiation and sustainability: A new stage of development in the Chinese container port system *Sustainability* **9** (3) 328
- [9] Yang J, Wang G W and Li K X 2016 Port choice strategies for container carriers in China: A case study of the Bohai Bay Rim port cluster *International Journal of Shipping and Transport Logistics* 8 129-152
- [10] Zhao B 2016 Facts and lessons related to the explosion accident in Tianjin Port China Natural Hazards 84 (1) 707-713
- [11] Zhao X L 2016 Research on gray fuzzy risk assessment in water transportation of dangerous goods 22nd International Conference on Industrial Engineering and Engineering Management (Atlantis Press) 725-732