



Engineering Ethics Factors and Prevention in Xiangshui Chemical Explosion

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Abstract. With the accelerating process of urbanization in China, the industrial safety risks faced by the urban public are increasing. A series of dangerous chemical explosion accidents not only caused casualties, economic losses and environmental damage to the production personnel and the surrounding people, but also exposed the relevant enterprises' own safety awareness is not high, safety management, emergency treatment deficiencies, there are many engineering ethics problems. Taking the explosion accident of Xiangshui chemical enterprise as an example, this paper analyzes the accident from the perspective of engineering ethics, and uses the analysis of engineering ethical inducements to find the prevention strategies for the accident of chemical production enterprises.

Keywords: Engineering ethics; Sense of responsibility; Explosion accidents

1 Introduction

With the continuous acceleration of China's urbanization process, urban populations are facing increasing industrial safety risks^[1]. A series of hazardous chemical explosions including the Tianjin Port explosion, G15 Expressway tanker explosion, and the February 11 Liaoning Huludao explosion have not only caused casualties among workers and nearby residents, economic losses, and environmental damage, but also exposed multiple engineering ethics issues such as insufficient safety awareness, poor safety management, and inadequate emergency response capabilities in related enterprises. Following the catastrophic August 12 Tianjin Binhai New Area explosion, a nationwide investigation identified approximately 1,000 chemical enterprises requiring relocation at an estimated cost of 400 billion yuan. This relocation necessity arises primarily because these facilities are located near residential areas or schools in densely populated regions, creating significant safety risks^[2]. The sheer number of chemical enterprises and the shocking consequences of accidents make each incident difficult for the public to reconcile. Weil and others have emphasized the importance of engineering ethics education for social development, which not only involves conceptual understanding but also influences engineers' attitudes towards learning skills and knowledge, as well

as their consideration of individuals, society, and the environment beyond the engineering itself in systems engineering.^[5-14]Essentially, these accidents and their root causes can be attributed to engineering ethics issues involving values, interests, and responsibilities - complex challenges that render industrial system management particularly difficult. This situation imposes new requirements on urban industrial administrators and relevant engineers to strengthen engineering ethics awareness, objectively recognize corporate values, implement safety responsibilities, promote enterprise safety development, and ensure public demands for safety and environmental protection while creating social benefits.

This paper will analyze engineering ethics considerations in industrial production through the case study of the March 12 Xiangshui Chemical Plant Explosion, and propose corresponding preventive measures based on the findings.

2 Verview and Impact of the Xiangshui Chemical Plant Explosion

2.1 Accident Timeline



Fig. 1. Aerial photograph of the accident scene

On March 21, 2019, at 2:00 PM, a warehouse at Tianjiayi Chemical Co., Ltd. in Jiangsu Province, which had long stored nitro waste, exploded due to poor ventilation and excessive density of accumulated nitrated materials, as shown in Figure 1. The buildup of heat triggered spontaneous combustion, which ignited nearby nitro waste and caused a chain explosion. The blast resulted in nearly 800 casualties, including 78 fatalities, 76 severe injuries, and 640 individuals hospitalized for observation. Surrounding schools and businesses suspended operations, and multiple power lines were damaged, leading to widespread outages, with direct economic losses reaching 1.986 billion yuan. Following the explosion, the Xiangshui County Fire Brigade launched emergency rescue operations. Medical teams from local and neighboring emergency centers rushed to the scene, supplemented by three batches of medical experts dispatched by the National Health Commission to assist in rescue efforts. The Ministry of Emergency Management

and the Ministry of Ecology and Environment conducted urgent assessments and guided the mitigation of water, air, and soil pollution. Meanwhile, the Jiangsu Provincial Government and Yancheng Municipal Government is sued official updates to manage public sentiment and maintain social stability through coordinated communication strategies.

2.2 Impact of the Accident

The consequences of the Xiangshui explosion primarily manifested in the following aspects: casualties among workers and nearby residents; property damage to production facilities and surrounding communities; environmental pollution involving toxic gases from the combustion of chemical substances, water contamination from rescue operations, and soil pollution; public panic and post-traumatic stress. Following the accident, local residents evacuated to areas away from the plant, while survivors suffered significant psychological trauma. Additionally, the widespread dissemination of exaggerated and false information online generated substantial negative social repercussions.

3 Engineering Ethics Root Causes Analysis of the Xiangshui Chemical Plant Explosion Incident

3.1 Analysis of Engineering Ethics Contributing Factors Based on Direct Causes of the Accident

The direct cause of the Xiangshui explosion accident was that the warehouse where Tianjiayi Chemical Co., Ltd. had stored nitrification waste for a long time due to poor ventilation, and the density of some nitrides was too large, which led to the spontaneous combustion of heat accumulation, which led to the violent combustion and explosion of other nitrides in the surrounding area. The thermal reactions of the accumulated substances may involve two types: autocatalytic and N-order. The autocatalytic reaction model is shown in formula (1), while the N-order reaction models are presented in formulas (2) and (3).^[15-20]

$$\frac{d\alpha}{dt} = A - \frac{E_a}{RT}(1-\alpha)^n \quad (1)$$

$$\frac{d\alpha}{dt} = A_2 \frac{E_{a2}}{RT}(1-\alpha)^{n_1}(a^{n_2+z}) \quad (2)$$

$$Z_0 = \frac{A_2 \frac{E_{a1}}{RT}}{A_2 \frac{E_{a1}}{RT}} = Z_0 \frac{E_{a2}}{RT} \quad (3)$$

The investigation showed that the accident was a major hazardous chemical explosion liability accident. As early as the initial development of the chemical industry, people recognized the dangers of exothermic reactions, but it was not until the 1960s and 1970s that a systematic understanding of these dangers was formed.^[3] Why do companies need to store nitrification waste in violation of regulations? Why is there no

reasonable accumulation in the storage warehouse? Why don't manufacturers have corresponding monitoring and testing measures? These questions have led us to think about the benefits and responsibilities of engineering ethics. The ultimate purpose of almost all enterprises to carry out production activities is to obtain economic benefits from them and meet the benefits of enterprise owners and relevant shareholders, but the vast majority of enterprises regard the enterprise's investment in safety equipment, safety management, emergency treatment and other inputs as a necessary increase in the cost of production of the enterprise, and do not follow the "Safety Production Law" for production activities, and even more in order to reduce costs, ignore laws and regulations, and use unreasonable production methods to produce, resulting in enterprises from top to bottom. From managers to employees, there is a lack of consideration for the interests of the public, which also reflects the problems in the values of many existing chemical enterprises. In addition, in the accident, there are also enterprise safety management departments, third-party safety evaluation companies, safety production departments and environmental protection departments do not work properly, do not abide by the law, violate morality, all parties did not point out and correct the problem in a timely manner after the problem appeared, and even there was a situation of fraud to hide potential safety hazards, resulting in the bitter fruit of the final explosion. .

3.2 Analysis of the Engineering Ethical Incentives Based on the Indirect Causes of the Accident

3.2.1 Production Enterprises Aspect.

The manufacturing enterprise lacks safety awareness. For its own interests, the enterprise continues to launch the production line for the aniline project and the nitration section despite the equipment not meeting standards, fully aware that the nitration waste is classified as toxic, harmful, flammable, and explosive chemical hazardous materials, yet it still stores them under unsafe conditions without strengthening the corresponding safety management.

The safety management is chaotic. The storage warehouse for nitrates does not have classified storage, and there is no clear inventory of the quantities and categories of hazardous materials within the warehouse. The management personnel do not have a reasonable management plan. As shown in Figure 2, The graph illustrating the relationship between marginal safety investment and marginal returns shows that MC represents the marginal safety investment curve and MR represents the marginal safety return curve. When safety investment is below the equilibrium point S_0 , the increase in safety investment is less than the reduction in accident losses. As a business, it is often necessary to position safety investment at the equilibrium point to ensure profit maximization. In this incident, the safety investment was clearly insufficient, leading to further expansion of accident losses.

The production enterprise has insufficient investment in safety. The company has not established a qualified warehouse, the fire protection facilities cannot ensure quality and quantity, the emergency response capability is poor, emergency drills are merely formal, and the handling of emergencies is inappropriate and untimely.

The safety education and publicity are inadequate, with daily safety education limited to slogans and banners, concealing the dangerous conditions of the enterprise from the surrounding community, resulting in significant losses for the community during and after the occurrence of the accident.

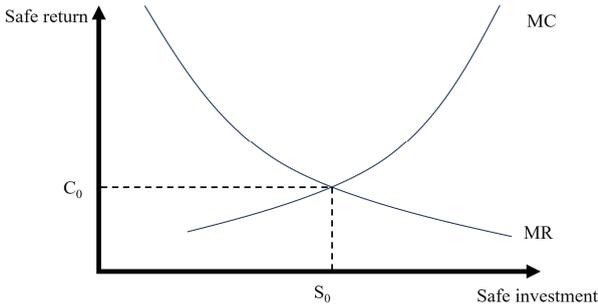


Fig. 2. The relationship between margin of safety investment and marginal returns.

As a large enterprise engaged in the production of hazardous chemicals, it should clearly define its safety responsibilities, ensure production under safety requirements, and guarantee the safety and health of the public. However, the enterprise has neglected this ethical issue in engineering, relaxed safety management, and lacked a sense of safety responsibility, leading to the occurrence of the accident. In Figure 3.

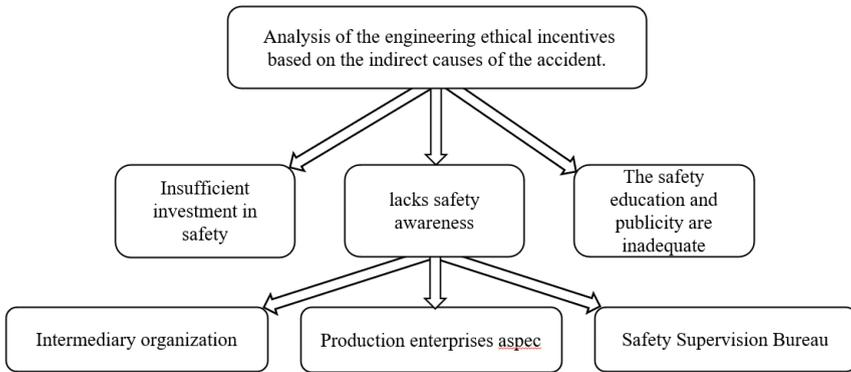


Fig. 3. Direct Causes of the Accident

3.2.2 Intermediary Organization.

The intermediary agencies engaged in fraudulent activities, issuing documents that were false and inconsistent with the actual situation for the enterprise, resulting in a significant amount of nitrated waste, a hazardous source, not being disclosed in a timely manner. This interfered with the regulatory work of emergency management departments, environmental protection departments, the Ministry of Housing and Urban-Rural Development, and other agencies. Suzhou Ketai Environmental Technology Co.,

Ltd. falsely reported the expected effects of cooling crystallization recovery of mixed dinitrobenzene. The Jiangsu Provincial Academy of Environmental Sciences subcontracted the environmental impact assessment report of this production company to other companies, yet still issued the report under the name of the Jiangsu Provincial Academy of Environmental Sciences. Jiangsu Tiangong Dacheng Safety Technology Co., Ltd. signed the safety evaluation report for this company, which was severely inconsistent with the actual situation, among other issues. A series of third-party evaluation agencies failed to fulfill their responsibilities truthfully, allowing hidden dangers of accidents to evade inspection repeatedly. Is it due to the inadequacy of these third-party companies that they cannot identify problems? Or is it their lack of engineering ethics and responsibility, solely pursuing the economic benefits provided by the production company while forgetting their important responsibilities in engineering ethics.

3.2.3 Safety Supervision Bureau.

Safety supervision is not in place, whether it is the daily inspection is not deep enough and not detailed enough, or the surprise inspection is full of loopholes, all of which show that the work of the safety supervision department is a formality. The degree of construction of the safety professional team is insufficient, and the proportion of people with safety professional learning in the team is not large. And in the entire regulatory system, there is no individual who dereliction of duty or even privately accepts bribes from production enterprises. The emergency management and environmental protection departments are not strict in the review and acceptance process of the resumption of production of enterprises. The huge impact and loss caused by the accident is the failure of many parties and departments, involving serious engineering ethics issues and engineering ethical interests. There is a lack of responsibility from the emergency management department to the planning department, and there is no mechanism to urge the enterprise to fundamentally complete the safety production requirements. The acceptance of bribes by personnel of individual departments is not only a matter of project interests, but also a serious issue of project responsibility. Among them, the housing and urban-rural development department has successively reissued 6 batches of construction permits for Tianjiayi Company, and one batch of them has issued 2 permits. If the illegal behavior can be stopped in time, it will be a wake-up call for the company to violate the rules and regulations, and the situation of illegal construction and illegal storage may not occur. If the environmental protection department discovers its illegal production and strictly stops it, there will be no illegal waste. Should economic interests come first or should safety responsibilities come first? In the final analysis, these issues are issues of engineering ethical responsibilities and engineering interests.

4 Accident Prevention Measures Based on the Perspective of Engineering Ethics

In the prevention of industrial safety accidents in urban areas, production enterprises, as the main entities, not only need to clarify their social responsibilities and ensure the

quality and quantity of safety production requirements but also must closely link the interests of the community with their own interests, and must not focus solely on their own benefits. Only in this way can the probability of safety accidents be reduced and the losses caused by accidents be mitigated. In Figure 4, This article will examine the preventive control measures for major hazardous chemical accidents from four aspects: improving relevant laws and regulations, enhancing inspection mechanisms, strengthening public supervision through active social opinion, and raising the level of engineering ethics in higher education.

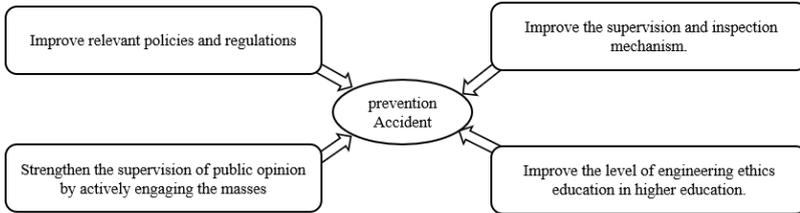


Fig. 4. Accident prevention measures

4.1 Improve Relevant Policies and Regulations

To fortify workplace safety safeguards, a systematic and multi-dimensional policy framework must be established: The implementation rules of the Work Safety Law should be revised to create comprehensive regulations covering all industries and operational processes, with specialized management regulations for high-risk sectors featuring dynamic adjustment mechanisms and triennial efficacy evaluations. A tripartite penalty mechanism encompassing credit sanctions, professional disqualifications, and criminal punishments will be implemented, imposing credit restrictions and industry entry bans on violators while enhancing administrative-criminal linkage protocols. Simultaneously, a closed-loop supervision model of "inspection-rectification-verification-tracking" will be adopted, incorporating third-party evaluation agencies and big data analytics to develop enterprise safety profiles. Cultural transformation will be driven through engineering ethics integration in qualification assessments, industry self-regulation standards, and tax incentives for safety-compliant enterprises. Supporting measures include establishing safety development funds and reforming liability insurance markets, complemented by tax certification systems encouraging safety investments. Technological empowerment will be achieved through an intelligent supervision system integrating IoT monitoring, blockchain-based evidence preservation, and AI-powered early warnings, with smart sensors deployed at critical hazard points. This integrated governance architecture combines regulatory constraints, technological support, and cultural guidance, transitioning enterprises from passive compliance to proactive safety innovation, ultimately forging a collaborative governance ecosystem involving government, businesses, employees, and society to ensure intrinsically safe production practices.

4.2 Improve the Supervision and Inspection Mechanism

Safety inspection is one of the effective means to ensure the safe operation of enterprises, therefore, relevant enterprises should timely revise and improve the supervision and inspection mechanism based on the characteristics of the enterprise, safety production status, environmental changes, etc., give full play to the role of supervision and inspection, and eliminate potential safety hazards in a timely manner^[4]. Improving the supervision and inspection mechanism is not only for government functional departments, but also for third-party evaluation enterprises. Only by supervising and restricting each other can the supervision and inspection mechanism be implemented. Third-party evaluation institutions should clarify their own responsibilities, ensure that they do their own work well, bind their own interests to the public, rather than to production enterprises, and provide accurate and scientific evaluation reports for government departments. The relevant government departments should not only believe in the evaluation report, but also have their own safety red lines to ensure that they can do a good job of the last hurdle for safe production. Production enterprises, evaluation enterprises, and government departments work together to clarify the ethical issues of the project, and ensure public health and safety while creating economic benefits.

4.3 Strengthen the Supervision of Public Opinion by Actively Engaging the Masses

In industrial enterprises, the general public often constitutes a vulnerable group and is also a victim group in safety accidents. Before an accident occurs, the public is often unaware of the safety hazards present in their surroundings, and they are even less informed about the specific types of hazards and how to rescue themselves during an incident. Whenever an accident occurs, the public not only has to endure threats to their lives, property, and health but also suffers significant psychological damage. This can lead to situations where people are hesitant to discuss or avoid hazardous situations altogether. Therefore, while strengthening safety evaluations and environmental assessments in industrial enterprises, it is essential to disclose information regarding existing hazards, types of dangers, and emergency response measures, and actively inform the surrounding community to alleviate the psychological pressure caused by the unknown and reduce the public's fear. At the same time, opportunities for public participation should be provided, allowing the public to engage in the decision-making and supervision processes of relevant projects, ensuring that while enterprises gain economic benefits, the interests of the community are not compromised.

4.4 Improve the Level of Engineering Ethics Education in Higher Education

The education of engineering ethics in our country started relatively late and has not yet formed a systematic curriculum. Both undergraduate and graduate students do not place enough importance on this course. However, studies from other developed countries indicate that learning through engineering ethics courses can significantly enhance students' awareness of engineering ethics and their sense of ethical responsibility,

thereby improving their decision-making abilities in engineering ethics in their future work and establishing a clear line of ethical responsibility. Therefore, it is essential to strengthen the awareness of engineering ethics in higher education to ensure that it can cultivate ethical awareness in schools, practice ethical responsibilities in society, and encourage engineering professionals to prioritize public safety and health in their actual work, guiding them to make choices that benefit the community when faced with ethical dilemmas. Additionally, students who receive a solid education in engineering ethics can serve as role models in the workplace, inspiring those around them to establish a consciousness of engineering ethics, which can gradually lead to the formation of an engineering ethics culture within enterprises from the bottom up. This is of significant importance for the safe development of industrial enterprises, especially chemical companies, as well as for environmental safety and the health and safety of the public.^[5]

4.5 Case Implications

On August 4, 2020, the explosion incident in Lebanon involved the storage of over 2,700 tons of ammonium nitrate for six years. The investigation into the incident revealed that, similar to the Xiangshui explosion, there were issues of chaotic production safety management, insufficient safety investment, and inadequate supervision. The enhancement of engineering ethics education has a certain universality worldwide, and improving the overall level of engineering ethics in society can gradually permeate various industries to ensure safe production.

5 Conclusion

The conflict between corporate interests and environmental safety, as well as the health and safety of the community, along with the low awareness of ethical responsibilities in production enterprises and third-party evaluation companies, is a deep-rooted cause of the explosion at the Xiangshui chemical plant.

The production enterprises, as the main entities responsible for preventing and controlling hazardous accidents, need to ensure quality and quantity in safety investments. When conditions permit, they may seek better safety measures, safety management, and safety culture to provide references for safety inspection agencies, rather than evading responsibility.

Third-party evaluation agencies should firmly align their interests with those of the public, avoid the phenomenon of self-assessment, and encourage production enterprises to fulfill their social responsibilities, promptly eliminate safety hazards, and prevent accidents or mitigate the negative social impacts of accidents.

The government functional departments should improve relevant policies and regulations, making the laws and regulations more specific, while also increasing the severity of penalties to avoid the phenomenon of substituting fines for corrections. This will promote the enhancement of corporate engineering ethics awareness, facilitate the formation of corporate engineering safety culture, ensure that production enterprises and evaluation enterprises fulfill their respective duties, and carry out responsibilities for

safety production, environmental protection, and social public responsibilities, effectively manage, eliminate the phenomenon of lax law enforcement, and effectively prevent accidents from occurring.

Coordinate enterprises to publicize and make non-sensitive information transparent, granting the public the right to know, reducing their psychological pressure, and allowing the public to participate in the decision-making process of relevant projects when necessary, ensuring that the production interests of enterprises are not disconnected from the interests of the public.

Enhancing engineering ethics education requires a three-dimensional coordination mechanism encompassing individuals, organizations, and society. At the individual level, establishing ethical certification systems for technical personnel with scenario-based vocational training is essential. Enterprises should develop ethics review committees and industry standard frameworks, while governments need to improve ethical early-warning mechanisms and incentive policies. Concrete measures include building digital education platforms, conducting industry-academia research collaborations, and incorporating ethical metrics into corporate ESG evaluations. This progressive development path from personal conduct norms to industry governance and policy safeguards ultimately constructs a production safety system rooted in cultural consciousness.

With the development of AI technology, the introduction of intelligent technology in safety management and regulation, along with the training and improvement of a rational engineering ethics intelligent agent, will enhance our ability to prevent accidents.

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