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Hazard Factors and Preventive Measures in Pesticide Formulation Processing and Production

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ABSTRACT

The production of pesticide formulations is characterized by highly toxic materials, complex processes, and significant risks, posing severe challenges to production safety. Based on the characteristics of pesticide formulation production processes, this paper systematically analyzes hazard factors in physical, chemical, and process aspects during production. It examines mechanical injuries, noise hazards, electrical risks, toxicity hazards, fire and explosion risks, corrosion hazards, operational risks, equipment failures, and storage and transportation dangers. Corresponding preventive measures are proposed for each type of hazard, including improving protective systems, enhancing process management, and establishing emergency response mechanisms. These recommendations aim to provide theoretical and practical guidance for improving the safety level of pesticide formulation production.

KEYWORDS

Pesticide formulations; Production process; Hazard factors; Safety prevention; Emergency management.

1. INTRODUCTION

Pesticide formulation production is a vital component of the chemical industry, playing a key role in supporting agricultural production. Currently, the scale of pesticide formulation production in China continues to expand, with an increasingly diverse range of products[1]. However, safety risks during production cannot be overlooked. The process involves various toxic and harmful raw materials, complex procedures, and numerous types of equipment, resulting in an intricate interplay of hazard factors[2]. In recent years, frequent safety incidents in the industry have caused casualties and property losses, exposing deficiencies in safety management during production. Therefore, conducting an in-depth study of hazard factors and preventive measures in pesticide formulation production is of great significance[3]. This paper analyzes the characteristics of production processes, systematically identifies various hazard factors, and proposes targeted preventive measures to serve as a reference for improving the safety level of pesticide formulation production.

2. PESTICIDE FORMULATION PRODUCTION PROCESSES AND CHARACTERISTICS

2.1. Production Process Flow

The production process of pesticide formulations typically includes several stages: raw material pretreatment, ingredient mixing, crushing and grinding, emulsification and suspension, and filling and packaging. During the raw material pretreatment stage, various pesticide active ingredients, additives, and solvents are weighed and pre-mixed. In the ingredient mixing stage, components are added to the reaction vessel according to the product formula and thoroughly stirred to ensure uniform material dispersion[4]. For emulsifiable concentrates and suspension concentrates, emulsifiers are added to an emulsification tank for high-speed shear emulsification, allowing the active ingredient to be stably dispersed in the aqueous phase. Powders and wettable powders are finely processed using pulverizers to improve the dispersibility and adhesion of the pesticide particles[5]. Once the formulations pass quality inspection, they proceed to automated filling lines for portioning, followed by packaging and storage on the packaging line.

2.2. Analysis of Process Characteristics

The production of pesticide formulations is characterized by raw material diversity, process complexity, and inherent risks. The process involves various toxic and hazardous chemicals, including active ingredients, organic solvents, and surfactants, some of which are flammable and explosive. The production utilizes a wide range of equipment, from pulverizers to reaction vessels, emulsification tanks, and filling lines, each requiring strict operational parameters. Parameters such as temperature, pressure, and stirring speed must be precisely controlled, and the process requirements for different formulation types vary significantly[6].Table 1 lists the key process parameters for major pesticide formulation types. It is essential to ensure that all parameters remain within the specified ranges to maintain consistent and reliable product quality. Additionally, steps such as material transfer, intermediate storage, and product packaging must strictly follow safety operation protocols to prevent accidents.

Table 1. Key Process Parameters for Major Pesticide Formulation Types

Formulation Type	Temperature Range (°C)	Pressure (MPa)	Stirring Speed (r/min)	Particle Size (μm)
Emulsifiable Concentrate	20–40	0.1–0.3	800–1200	-
Emulsion	15–35	0.2–0.4	2000–3000	1–5
Suspension Concentrate	15–30	0.2–0.5	1500–2500	2–10
Wettable Powder	Ambient Temperature	Atmospheric Pressure	500–1000	5–20

3. HAZARD ANALYSIS

3.1. Physical Hazards

3.1.1. Mechanical Hazards

Mechanical hazards in pesticide formulation production primarily arise from various operating equipment such as pulverizers, mixers, pumps, and packaging machinery. These machines have high-speed rotating components, typically operating at speeds of 800–3000 revolutions per minute, posing risks of entanglement or collision injuries. Pressure vessels operate under working pressures of 0.2–0.5 MPa, and an explosion could cause severe harm to nearby personnel due to shockwaves and fragments, as illustrated in Figure 1. Conveyor belts and transmission systems often exert forces exceeding 2000 N at pinch points, and failures in protective devices may result in limb injuries. Statistics indicate that approximately 65% of mechanical injuries are related to moving parts, 25% involve pressure vessels, and 10% are caused by other mechanical factors[7].

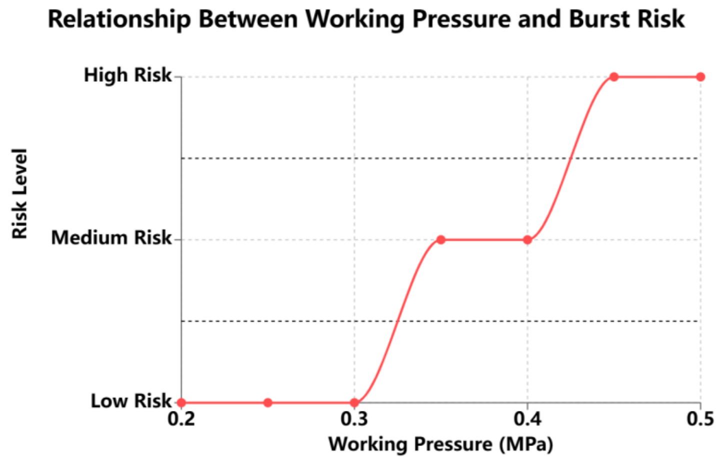

Figure 1. Relationship Between Pressure and Explosion Risk

3.1.2. Noise Hazards

Noise in formulation production workshops mainly originates from pulverizing equipment, pumps, and mechanical vibrations. Large pulverizers can generate noise levels of 95–105 dB during operation, exceeding the 85 dB limit set by national industrial noise health standards. High-speed mixers and emulsifiers produce noise levels of 75–85 dB during high-speed operation, and simultaneous operation of multiple machines can lead to cumulative noise effects. There is a significant correlation between noise exposure duration and the degree of harm, with long-term work in high-noise environments increasing the risk of occupational hearing loss. Figure 2 shows the noise distribution in different work areas.

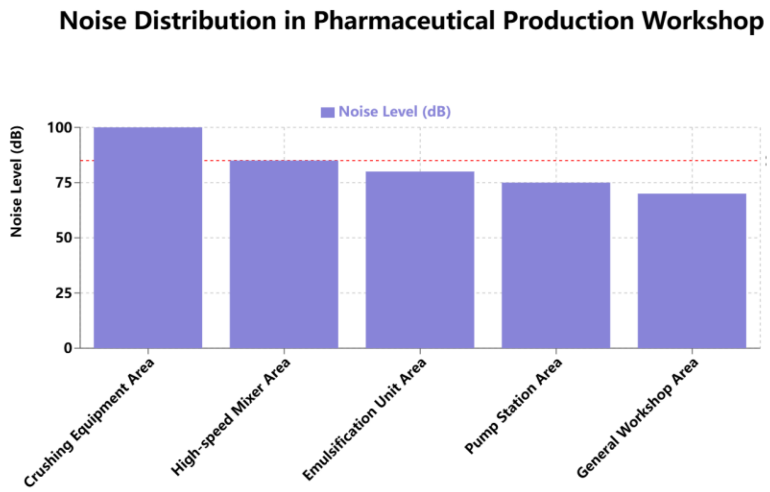

Figure 2. Noise Distribution in Different Work Areas

3.1.3. Electrical Hazards

Electrical hazards in pesticide formulation production are primarily associated with the use of electrical equipment and explosion-proof requirements. Production workshops commonly use 380V three-phase power and 220V single-phase power, with motor power ranging from 5 kW to 75 kW. Explosion-proof electrical insulation resistance must exceed 0.5 MΩ, but factors such as humidity and corrosive substances may reduce the insulation resistance to dangerous levels during operation. Grounding resistance for power distribution systems must remain below 4Ω, and leakage protection devices should be set with an operating current of 30 mA and a response time of no more than 0.1 seconds. Statistics show that 80% of electrical accidents are caused by equipment leakage, 15% by aging circuits, and 5% by failure of explosion-proof electrical components. Conductive dust and flammable vapors in the production environment further increase the risk of electric shock[8].

3.2. Chemical Hazards

3.2.1. Toxic Hazards

Toxic hazards in pesticide formulation production mainly stem from active ingredients, organic solvents, and formulation products. As shown in Table 2, active ingredients exhibit the most significant toxicity. For instance, the lethal dose (LD50) of organophosphorus pesticides typically ranges from 50 to 500 mg/kg. These substances can cause acute poisoning through skin contact, inhalation, or accidental ingestion. Volatile organic solvents often exceed permissible concentrations in workshop air. For example, xylene concentrations in workshop air range from 50–100 mg/m³, far exceeding the national occupational health standard limit of 20 mg/m³[9]. A survey of 100 pesticide companies revealed an occupational poisoning rate of 0.3%, with 85% of cases involving chronic poisoning and 15% acute poisoning.

Table 2. LD50 Comparison

Pesticide Category	Representative Pesticide	LD50 Range (mg/kg)
Organophosphorus Pesticides	Malathion	50 – 500
Carbamate Pesticides	Imazapyr	300 – 1,000
Herbicides	Glyphosate	>5,000
Fungicides	Mancozeb	2,000 – 4,000

3.2.2. Fire and Explosion

The risks of fire and explosion in formulation production primarily arise from flammable solvents and combustible dust. Common solvents like xylene and methanol have flash points of 30°C and 12°C, respectively, making them highly likely to form explosive mixtures under production conditions. Other solvents, such as acetone and ethanol, exhibit similar explosive potential when their vapors mix with air within specific concentration ranges. Dust explosions typically occur when dust concentrations exceed 20–60 g/m³, and ignition sources like open flames or static sparks are present.

Potential ignition sources during production include static electricity accumulation, sparks from mechanical friction, and electrical equipment failures[10]. In processes such as raw material feeding and grinding, dust concentrations often reach explosive limits. Combined with flammable solvent vapors in the workshop environment, this creates a high risk of explosive mixtures. Figure 3 illustrates the fire and explosion risk levels in different areas, highlighting the high-risk nature of production zones, necessitating stringent preventive measures.

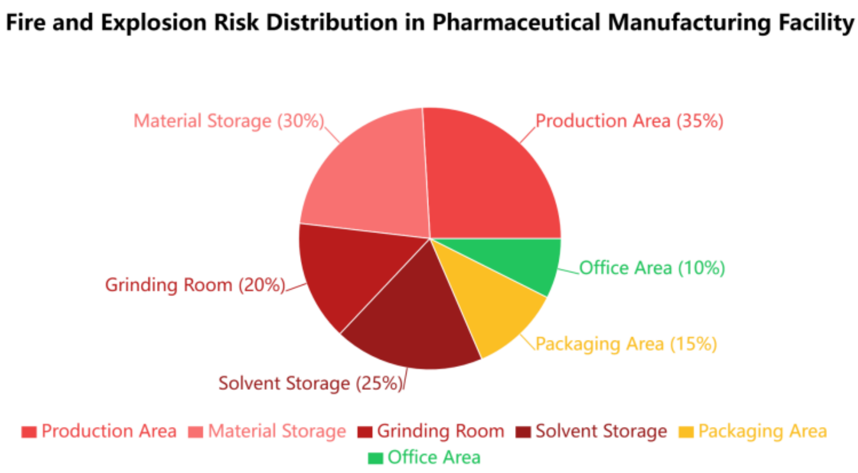

Figure 3. Fire and Explosion Risk Levels in Different Areas

3.2.3. Corrosion Hazards

Corrosion hazards in pesticide formulation production affect equipment, pipelines, and protective gear. Acidic and alkaline media used in production have pH ranges of 2–12, causing significant corrosion to metallic equipment. For instance, carbon steel pipelines in acidic media experience corrosion rates of 0.5–2.0 mm/year. Organic solvents cause swelling in rubber seals and plastic pipelines, leading to seal failure and pipeline rupture[11].Statistics show that approximately 60% of equipment leakage incidents are related to corrosion, with 40% involving pipeline corrosion, 35% equipment corrosion, and 25% seal failure. Personal protective equipment, such as rubber gloves, also deteriorates rapidly in organic solvents, with service life reduced from the standard 480 minutes to under 120 minutes.

3.3. Process Hazards

3.3.1. Operational Risks

Operational risks in pesticide formulation production mainly involve process parameter control, material addition, and equipment operation. Improper control of process parameters can lead to product quality issues and safety hazards. For example, when the deviation in stirring speed during emulsification exceeds ±10% of the set value, it can cause the emulsion to become unstable and separate. In the material addition stage, too fast a feeding rate can cause a rapid increase in the pressure of the reaction vessel and generate dust, as shown in Figure 4. According to statistics from a pesticide company over the past five years, safety incidents caused by operational errors are distributed as follows: 35% from process parameter control deviations, 28% from improper material addition, 25% from equipment misoperation, and 12% from improper emergency response. The experience and skill level of operators are inversely correlated with accident occurrence rates[12].

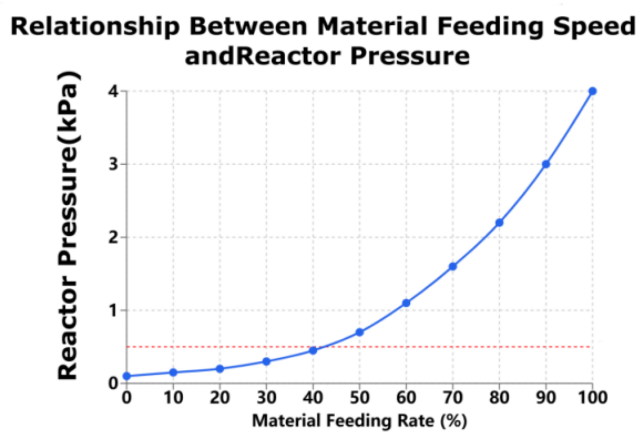

Figure 4. Material Addition Rate and Reaction Vessel Pressure Relationship

3.3.2. Equipment Failures

Equipment failures in formulation production primarily include mechanical failures, instrument malfunctions, and seal failures. For key equipment like reaction vessels, emulsifiers, and pumps, the frequency of mechanical failures increases with usage time. After 5,000 operating hours, the failure rate significantly rises. The accuracy of instruments for measuring pressure, temperature, and flow gradually decreases with time, with an annual deviation rate of 5%–8%. Mechanical failures mainly involve bearing wear, impeller damage, and shaft seal leakage, which lead to increased vibration and decreased efficiency. Instrument malfunctions are reflected in larger measurement data deviations, unstable signal transmission, and reduced control accuracy, affecting the precise control of process parameters. Seal failure usually occurs at flange connections, valve seals, and equipment interfaces, leading to material leakage and environmental pollution. Particularly in corrosive media and high-temperature, high-pressure conditions, the degradation speed of sealing materials increases, and maintenance becomes more difficult[13-14]. Figure 5 shows the distribution of major equipment failure types in a pesticide company, reflecting the main characteristics and occurrence patterns of equipment failures.

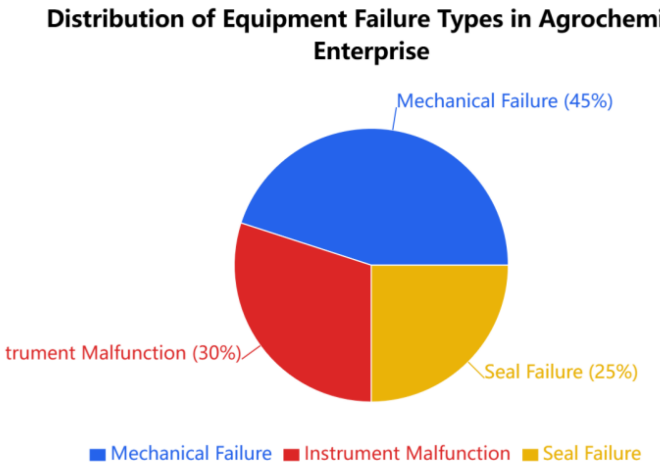

Figure 5. Distribution of Major Equipment Failure Types in a Pesticide Company

3.3.3. Storage and Transport Hazards

Storage and transport hazards for pesticide formulations primarily involve safety issues during warehousing and transportation. The temperature of raw material and finished product warehouses must be strictly controlled within the range of 5–35°C, with relative humidity maintained between 45%–75%. According to accident statistics from a pesticide company, the analysis of accident causes in storage and transport stages shows: 40% due to packaging damage, 30% due to improper storage conditions, 20% due to improper loading and unloading operations, and 10% due to accidents during transportation[15-16]. Leak detection systems in large storage tank areas show an annual leakage frequency of approximately 0.05 leaks per tank per year, with minor leaks accounting for 85%, small leaks 12%, and large leaks 3%, as shown in Table 3. During material transportation, packaging damage caused by vehicle bumps is the main risk factor, and pressure fluctuations during pressurized tank transport also pose significant safety hazards.

Table 3. Storage Tank Leakage Detection

Leak Type	Percentage (%)	Annual Leakage Frequency (per tank per year)
Minor Leaks	85	0.0425
Small Leaks	12	0.006
Large Leaks	3	0.0015

4. SAFETY PREVENTION MEASURES

4.1. Prevention of Physical Hazards

To address physical hazards in pesticide formulation production, a comprehensive protection system and management procedures must be established. For mechanical protection, all operating equipment must be equipped with protective covers or barriers. Transmission parts should use interlocking devices to ensure that personnel cannot access hazardous areas while the equipment is in operation. A shutdown and lockout procedure must be followed during equipment maintenance. For noise control, vibration-damping and noise-reducing measures should be implemented for high-noise equipment, including installing vibration pads, setting up soundproof enclosures, and improving equipment structures. This will ensure that workshop noise is controlled below 85 decibels[17]. Additionally, workers should be provided with specialized noise-protection earplugs and earmuffs, and it is mandatory for them to wear them correctly. For electrical safety, all electrical equipment must be explosion-proof, and electrical circuits should be regularly tested for insulation resistance. The grounding system should be reliable, and leakage protection devices must be installed and periodically tested for sensitivity and response time. Warning signs should be placed in areas with electrocution risks, and a complete system for live work and maintenance should be established, ensuring that personnel are properly certified.

4.2. Prevention of Chemical Hazards

Chemical hazard prevention requires comprehensive measures across source control, process management, and emergency response. For toxicity hazards, the production workshop must be equipped with a proper ventilation and dust removal system to ensure that the concentration of harmful gases is below the permissible exposure limits. Toxic gas detection and alarm devices should be installed at key positions, linked with the ventilation system. Workers must use personal protective equipment (PPE) correctly, including gas masks, protective clothing, and gloves, and regular occupational health check-ups should be conducted. To prevent fire and explosion hazards, explosion-proof electrical equipment must be used in flammable and explosive areas, and combustible gas detection and alarm systems must be installed[18]. A comprehensive set of anti-static measures should be implemented, including grounding equipment, anti-static devices, and anti-static clothing. The storage areas must strictly follow fire partitioning and spacing requirements and be equipped with adequate fire-fighting facilities. For corrosion protection, the materials used for equipment and pipelines should consider corrosion resistance, and appropriate anti-corrosion coatings or linings should be applied. Regular wall thickness measurements and maintenance should be carried out, and inspection and maintenance should be strengthened. Any corrosion risks should be addressed promptly to prevent leakage accidents caused by corrosion.

4.3. Prevention of Process Hazards

To ensure process safety, a robust safety management system and operating procedures must be established. For operational risk prevention, a comprehensive process parameter monitoring system should be implemented, using Distributed Control Systems (DCS) to automatically control and interlock critical parameters, ensuring that the process parameters always remain within a safe range. Employee training and assessments should be strengthened, and standardized operating procedures and safety operation instructions should be established. Regular emergency drills should be conducted.For equipment failure prevention, an equipment management information system should be set up, and predictive maintenance strategies should be implemented, utilizing technologies such as vibration monitoring and infrared testing to identify potential equipment issues in a timely manner[19]. A comprehensive spare parts management system should be established to ensure adequate reserves for key equipment components.In terms of storage and transportation safety prevention, a management system for the entry and exit of hazardous chemicals should be established, along with zone-based and category-based storage practices. Proper leak detection and emergency response facilities should be built. Transport vehicles must have hazardous material transport certification, drivers must be licensed, transport routes must avoid densely populated areas, and a transportation process monitoring and emergency response mechanism should be put in place.

5. CONCLUSION

This study systematically analyzes the hazards and preventive measures in the pesticide formulation production process, leading to the following conclusions: Among physical hazards, mechanical injuries account for the highest proportion (65%), followed by noise and electric shock hazards. Among chemical hazards, toxicity risks result in a career poisoning incidence rate of 0.3%, with chronic poisoning accounting for 85%. Fire, explosion, and corrosion hazards are also significant risk sources. In the process, operational errors and equipment failures are the main risks, and packaging damage in the storage and transportation phase accounts for 40% of accidents. This study has limitations in terms of equipment failure prediction and emergency plan improvement. Future research should focus on the development and application of intelligent monitoring and early warning systems, establishing risk assessment models based on big data analysis to enhance the inherent safety of the pesticide formulation production process. Furthermore, research on new environmentally friendly pesticide formulation technologies should be strengthened to reduce hazards in the production process.

REFERENCES

[1] Khayatnezhad M, Nasehi F. Industrial pesticides and a methods assessment for the reduction of associated risks: a Review[J]. Advancements in Life Sciences, 2021, 8(2): 202-210.

[2] Sookhtanlou M, Allahyari M S, Surujlal J. Health risk of potato farmers exposed to overuse of chemical pesticides in Iran[J]. Safety and Health at Work, 2022, 13(1): 23-31.

[3] Kalyabina V P, Esimbekova E N, Kopylova K V, et al. Pesticides: formulants, distribution pathways and effects on human health–a review[J]. Toxicology reports, 2021, 8: 1179-1192.

[4] Wei Y, Pang Y, Ma P, et al. Green preparation, safety control and intelligent processing of high-quality tea extract[J]. Critical reviews in food science and nutrition, 2024, 64(31): 11468-11492.

[5] Standard-Diagnostics E. PM 7/98 (5). Specific requirements for laboratories preparing accreditation for a plant pest diagnostic activity[J]. EPPO Bull, 2021, 51: 468-498.

[6] Ullah I, Zhao L, Hai Y, et al. Metal elements and pesticides as risk factors for Parkinson's disease-A review[J]. Toxicology reports, 2021, 8: 607-616.

[7] Abdollahzadeh G, Sharifzadeh M S. Predicting farmers' intention to use PPE for prevent pesticide adverse effects: an examination of the health belief model (HBM)[J]. Journal of the Saudi Society of Agricultural Sciences, 2021, 20(1): 40-47.

[8] Dinu M, Pagliai G, Scavone F, et al. Effects of an olive by-product called pâté on cardiovascular risk factors[J]. Journal of the American College of Nutrition, 2021, 40(7): 617-623.

[9] Kambey C S B, Campbell I, Cottier-Cook E J, et al. Seaweed aquaculture: a preliminary assessment of biosecurity measures for controlling the ice-ice syndrome and pest outbreaks of a Kappaphycus farm[J]. Journal of Applied Phycology, 2021, 33(5): 3179-3197.

[10] Guo C, Wang L, Chen N, et al. Advances in research and utilization of botanical pesticides for agricultural pest management in inner mongolia, china[J]. Chinese Herbal Medicines, 2024, 16(2): 248-262.

[11] Ma, K., & Shen, J. (2024). Interpretable Machine Learning Enhances Disease Prognosis: Applications on COVID-19 and Onward. arXiv preprint arXiv:2405.11672.

[12] Ma, K. (2024). Employee Satisfaction and Firm Performance: Evidence from a Company Review Website. International Journal of Global Economics and Management, 4(2), 407-416.

[13] Zhang J, Xiang A, Cheng Y, et al. Research on Detection of Floating Objects in River and Lake Based on AI Image Recognition[J]. Journal of Artificial Intelligence Practice, 2024, 7(2): 97-106.

[14] Xing Z, Li H, Liu W, et al. Spectrum efficiency prediction for real-world 5g networks based on drive testing data[C]//2022 IEEE Wireless Communications and Networking Conference (WCNC). IEEE, 2022: 2136-2141.

[15] Du W, Ge J, Sun S. Economic forecast of the southern China on BP neural network---Taking Chongqing as an example[C]//Proceedings of the 6th International Conference on Financial Innovation and Economic Development (ICFIED 2021). Atlantis Press, 2021: 614-618.

[16] Li M, Sui H. Causal Recommendation via Machine Unlearning with a Few Unbiased Data[C]//AAAI 2025 Workshop on Artificial Intelligence with Causal Techniques. 2025.

[17] Cheng Y, Wei Y, Liao H. Optimal sampling-based sequential inspection and maintenance plans for a heterogeneous product with competing failure modes[J]. Reliability Engineering & System Safety, 2022, 218: 108181.

[18] Cheng Y, Wang J, Wang Y. A user-based bike rebalancing strategy for free-floating bike sharing systems: A bidding model[J]. Transportation Research Part E: Logistics and Transportation Review, 2021, 154: 102438.

[19] Yang C, Li P, Ding X, et al. Mechanism for the reactivation of the peroxidase activity of human cyclooxygenases: investigation using phenol as a reducing cosubstrate[J]. Scientific Reports, 2020, 10(1): 15187.