

Comparison and Inspiration of Coal Mine Safety between China and the US

Jie Guo ^{1,*}, Qigen Deng ^{2,3,4}

¹ Shanxi Jincheng Anthracite Coal Mining Group Pingshang Coal Industry Co., Ltd., Jincheng 048000, China

² School of Safety Science and Engineering, Henan Polytechnic University, Jiaozuo 454003, Henan, China

³ State Key Laboratory Cultivation Base for Gas Geology and Gas Control, Henan Polytechnic University, Jiaozuo 454003, China

⁴ Collaborative Innovation Center of Coal Safety Production of Henan Province, Jiaozuo 454003, Henan, China

* Correspondence: 2644973201@qq.com

Abstract: The coal mine safety situation of US has experienced a high incidence of accidents and rapid decline period, but so far, it has tended to be safe and stable for a long time, 9 people dead and the death rate per million ton coal in coal mine was 0.012 in 2016. In the past 15 years, the death toll of coal mine accidents in China dropped from a high of 6995 in 2002 to 538 in 2016, and the death rate per million ton coal fell to 0.156. Although coal mine safety has been greatly improved, the death toll and the death rate per million ton coal in China are still more than ten times or even tens of times higher than in the United States. This paper by analyzing the development process of coal mine safety in China and US, compares the coal mine safety between China and US from the aspects of laws and regulations, supervision systems, trade unions, education and training, natural conditions and accident investigation. Analyzed the valuable experience gained in coal mine production safety in US, and probes into the ways to improve coal mine safety production in China.

Keywords: China and the US; safety situation of coal mine; safety comparative; accident

1. Introduction

Both China and the United States are major coal producing and consuming countries, In the United States, coal mines have basically put an end to major accidents and the death toll has basically stabilized. In recent years, the situation of coal mine safety has been greatly improved in China. However, the total number of accidents and the death rate per million ton coal in China are still more than ten times and even several times higher than in the United States, The situation of the coal production safety situation is still not optimistic. By comparing the safety of coal mines in China and the United States, we hope to learn from the beneficial practices of coal mines in the United States and try to provide some helpful suggestions for the safety of coal mines in China.

2. Safety Situation of Coal Mine

Currently, the US is one of the countries with the lowest death rate per million tons of coal mines among the world's major coal producing countries. However, throughout the development of the coal industry in the United States the coal mine safety situation has also experienced frequent accidents (the difficult age with many casualties), the process of technological innovation, strengthening of legislation and supervision, and finally the transition to the period of low accidents in production safety. Between 1903 to 1930, the average annual number of deaths due to accidents was as high as 2000, and reached its highest level in 1907, the annual death toll of which was 3242, The number of deaths thereafter dropped year by year and dropped to below 1000 after 1948. By the 1970s, with the regulations improvement of coal mine safety in the USA, the gradual improvement of production technology and mechanization, the continuous improvement of safety technology and equipment, the continual improvement of workers' qualifications and the implementation of the Federal Mining Safety and Health Law, the annual number of fatalities dropped to less than 150, below 90 after 1985 and below 50 after 1993. In the 21st century, coal mine accidents further decreased, except for the underground gas explosion caused by lightning strikes in Sago coal mine, West Virginia, in 2006, resulting in 12 deaths and a gas explosion at a subsidiary of Massey Energy Company., the capital of West Virginia in 2010, dead 25 people (the largest mine accident in the United States in more than 30 years). At present, the death toll from coal mine accidents has tended to stabilize, with the most serious accidents rarely occurring, the death rate per million tons is extremely low. In 2016, the number of coal mine accidents hit a record low, with a death toll of only 9 and the death rate per million ton coal falling from the maximum of 6.78 in 1907 to about 0.012 in 2017. Currently, the U.S. coal mining industry is one of the most enviable sectors of safety in all industries in the country, with a higher safety index than the retail industry. The death toll of coal mine accidents in the US from 1900 to 2016 is shown in Figure 1 [1,2].

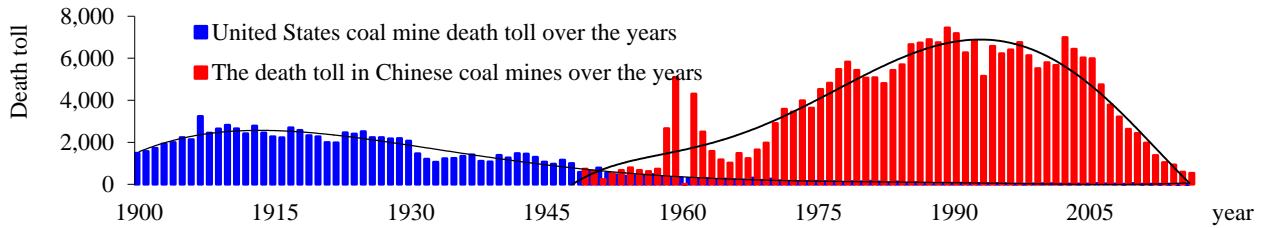


Figure 1. The histogram of death toll of coal mine in US from 1900 to 2017 and in China from 1949 to 2017.

We can get a linear relationship of deaths in coal mine accidents between China and the United States.
 $y = 4E-06x^5 - 0.0013x^4 + 0.1749x^3 - 10.092x^2 + 196.3x + 1367, R^2 = 0.9638$ (USA).

$y = 0.0001x^5 - 0.0519x^4 + 8.3447x^3 - 647.42x^2 + 24466x - 361811, R^2 = 0.8679$ (China).
 The trend of the death rate per million ton coal of coal mines in US is shown in Figure 2 [2,3].

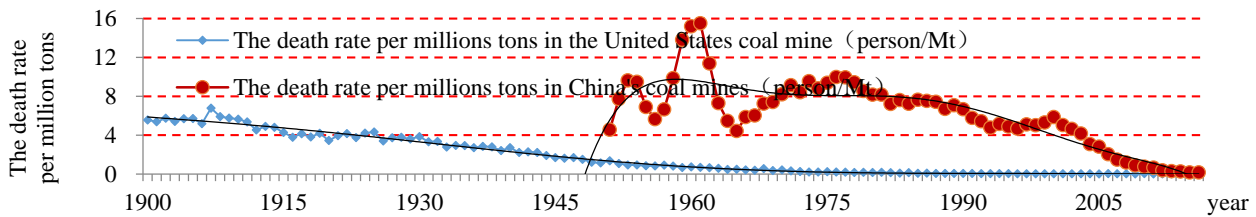


Figure 2. The trends of death rate per million ton coal of coal mine in US from 1900 to 2017 and in China from 1949 to 2017.

We can get a linear relationship of death rate per million ton coal between China and the United States.
 $y = 3E-11x^6 - 1E-08x^5 + 1E-06x^4 - 6E-05x^3 + 0.0002x^2 - 0.0687x + 5.9388, R^2 = 0.9826$ (USA).
 $y = -1E-08x^6 + 7E-06x^5 - 0.0015x^4 + 0.1747x^3 - 11.046x^2 + 366.83x - 4988.8, R^2 = 0.7334$ (China).

coal mine shown in Figure 3 [4], the transportation accidents account for 26.32% of all kinds of accidents, roof fall accidents account for 16.45% of all kinds of accidents, and mechanical accidents account for 12.5% of all kinds of accidents. Between 2014 and 2016, the power transmission and machinery operations were the leading cause of fatalities. In 2014, a total of 5 people died as a result of haulage, 5 people died from heavy machine-related operations and 5 out of 9 people were killed in 2016 died of power transportation and machine work.

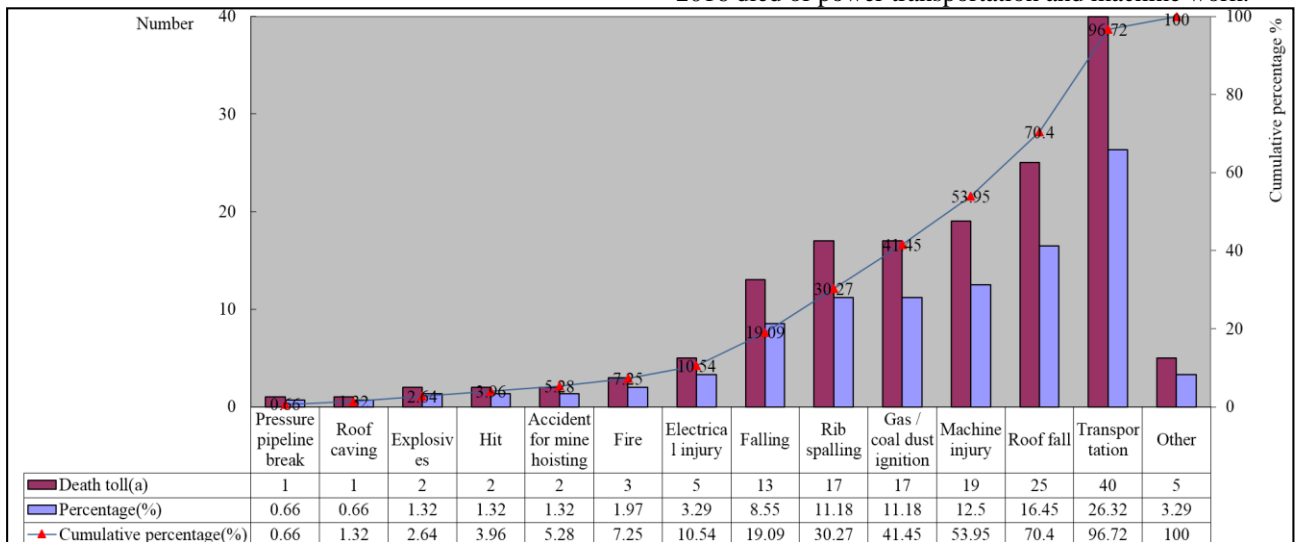


Figure 3. Accident category of coal mine in US from 2005 to 2009.

Coal production in the United States has basically remained at 0.8-1 billion short tons since 1989 (100 million short tons = 90.718474 million tons). At present, China's coal production accounts for about 45-50% of the

world's total coal output, reaching a historical high of 3.87 billion tons in 2014 and 3.41 billion tons in 2016, as shown in Figure 4.

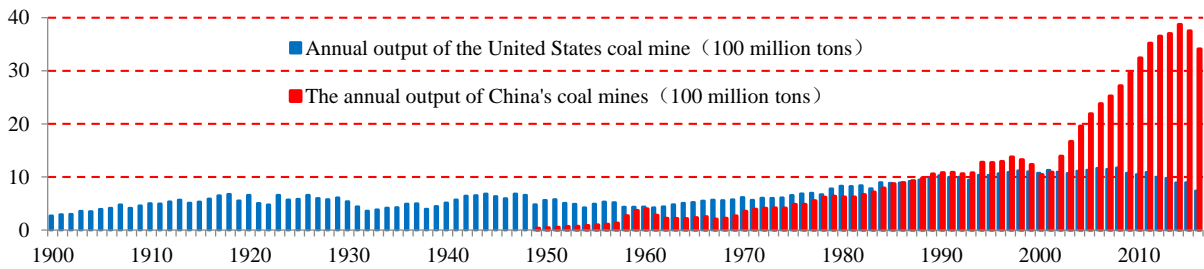


Figure 4. The coal production histogram of US from 1900 to 2016 and China from 1949 to 2016.

The coal mine accident in China dropped from 6995 in 2002 to a record low in 2017, with 375 deaths a year, as shown in Figure 1 [1,2]. The death rate per million tons coal of coal mines dropped from 5.86 in 2000 to 0.106 in 2017, as shown in Figure 2 [2,5]. In China, major accidents in coal mines have not been fundamentally reversed yet, the major accidents occurring in 2016 showing a clear rebound over the previous year, of the total, 11 were major accidents with 194 deaths, an increase of 120% and 128% respectively. Coal mine roof accidents, as accidents have been the major accidents in China's coal

mines [2,5,6]. In 2010-2015, there were 477 gas accidents in China's coal mines with 2291 fatalities, accounting for 10.0% of the total number of fatal accidents and 27.0% of the total number of deaths respectively, with an average of 4.8 deaths per accident. In 2010-2015, there were 2239 roof accidents and 2741 deaths, accounting for 46.0% of the total number of deaths accident and 33.0% of the total number of deaths, with an average of 1.22 deaths per accident. The number of accidents and death tolls in China's coal mines from 2010 to 2015 are shown in Table 1, and as shown in Figure 5 [7-9].

Table 1. Statistics data of main disasters deaths of china's coal mines from 2010 to 2015.

Years	Roof		Gas		Fire		Blasting		Electrical and Mechanical		Transport		Flood		Other	
	Occur rences	Death toll	Occur rences	Death toll	Occur rences	Death toll	Occur rences	Death toll	Occur rences	Death toll	Occur rences	Death toll	Occur rences	Death toll	Occur rences	Death toll
2010	702	829	135	623	12	224	34	37	71	78	246	281	38	168	155	193
2011	567	665	119	533	4	192	32	35	57	57	239	279	44	34	139	178
2012	366	459	72	350	5	122	24	25	56	58	145	201	24	27	87	142
2013	274	325	59	348	3	89	16	18	41	43	109	124	21	16	81	104
2014	196	292	47	266	1	4	13	19	36	37	83	103	19	79	114	134
2015	134	171	45	171	2	23	7	7	31	31	62	68	12	64	52	53

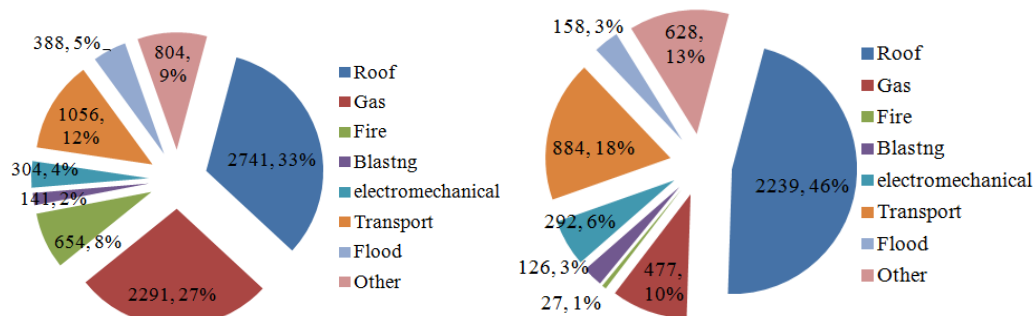


Figure 5. The distribution of accident category, deaths and the number of accidents in China's coal mine from 2010 to 2015.

3. Comparative Analysis of Coal Mine Safety in China and US

3.1. Comparison of Laws and Regulations

The legal system of coal mine production safety is rigorous, complete, authoritative and operational in the

United States. Its legislation, law enforcement and compliance are shown in Tables 2 and 3. With the introduction of relevant restraint mechanism. The warning and operability of the punishment are very strong. The criminal punishment procedure is more standardized [4-6].

Table 2. The comparison of safety laws and regulations in coal mines of US.

Coal mine safety legislation of U.S.		
Years	Statute	Major content
1891	United States coal mine safety regulations	The first law on mine safety
1952	United States coal mine safety management law	It contains 37 safety and health standards
1966	Federal mine safety law	Set mandatory safety and health standards, and establish some safety inspection system and punishment methods
1969	Federal Coal Mine Safety and Health Act	The safety facilities and conditions of coal mines have been established, and the MESA is set up. The safety inspector can be checked at any time, have the power of stopping work and stopping coal production in the case of emergency.
1977	Federal Mine Safety and Health Act	It is the supreme law of the national mine safety and health supervision. MSHA has been established, the normalization of safety inspection has been established, the accountability system for accident liability has been formulated, and the "raid system" has been defined and the system of joint and several liability has been established.
1995	Coal Mine Safety Supervision Procedures	It stipulates the procedures that coal mine safety inspectors must follow in the performance of their duties
1998	Code of Federal Regulations (Mineral Resources Volume)	The code can be put forward and revised every year on the basis of actual needs. It is highly operable.
2006	Coal Mine Improvement and New Emergency Response Act	The law requires the popularization of the personnel positioning system, which requires at least two mine rescue teams in each coal mine
2013	Coal Mine Safety Protection Act	Ensure that there are a sufficient number of well-trained coal mine safety inspectors. Allows immediate families of victims of mines to appoint representatives to participate in government investigations into mine accidents

Note: The situation of law enforcement in coal mine of US: The law enforcement is rigorous and the independence of supervision is very strong. The vertical coal mine safety regulatory system has been established and a rotation-type supervisory personnel system has been set up. Strict management and investigation system makes the inspector's law enforcement behavior very cautious and the phenomenon of infrequency, such as bribery and other violations of the law is rare. Law-abiding in coal mine of US: The cost of the accident is very high. The law guarantees the miners the right to participate in safety management, supervision and reporting. Therefore, the production operators and workers are in good compliance with the law.

Table 3. The comparison of safety laws and regulations in coal mines of China.

Coal mine safety legislation of China		
Years	Statute	Major content
1950	Trial regulation of coal mine technology safety	It standardizes the behavior of the workers and standardizes the safety operation of the coal mine
1982	Mine safety regulations	It has played a great role in the safety production of the mine at that time
1992	Law of the People's Republic of China on Safety in Mines	Protection of workers' safety in mines and quarries
1996	Law of the People's Republic of China on the Coal Industry	There are some contents about the safety of the coal mine, which have been modified many times.
2000	Regulations on Safety Supervision over Coal Mines	The law has been provided for the safety supervision and inspection in the coal mine industry. It has filled the blank of China's coal mine safety supervision legislation, which marks the legalization of coal mine safety work in China.
2002	Production Safety Law of the People's Republic of China	It is the first comprehensive law to emphasize the safety of the workplace
After many revisions	Coal mine safety regulations Provisions on Prevention and Control of Coal and Gas Outbursts Accident Report and Investigation Processing Rule	The coal mine safety legal system, it is supplemented by relevant judicial interpretations and important normative documents, and based on the department rules and regulations. It has a great effect on the safety of coal mine in China.

Note: There are more than 80 kinds of administrative regulations and more than 100 department rules and regulations in China. The situation of law enforcement in coal mine of China: Have made a significant achievements. But there are still some problems, such as the intersecting of the functions between the safety supervision department and the industry competent department, individual administration, the unidentified power and responsibility, the multiple law enforcement, and the repeated training. The efficiency of the law enforcement officer is not high, and the right of free discretion is too big. Law-abiding in coal mine of China: The practitioners have serious shortcomings in the law abiding, and the legal consciousness of the managers is weak. The miners' consciousness of law-abiding and safeguarding their rights is more indifferent.

China's coal mine safety laws and regulations system is a comprehensive system with various forms and levels. The legislative objectives are diversified, the legal system mechanism and responsibilities are flawed, the system is imperfect and unsmooth, and the operability is not strong. There are some omissions in the law of investigating the responsibility of mining accidents, the difficulty of miners' rights protection and the lack of law enforcement in coal mine safety supervision.

3.2. Comparison of Monitoring System

The United States established the Mine Safety and Health Administration (MSHA) in 1978. MSHA represent the state to supervise the safety and health of mines throughout the country. It has a coal mine safety and health Administration that is responsible for monitoring and controlling over 1300 coal mines in 27 states on safety and health supervise. There are 11 regional inspection

offices and 37 offices in major coal-producing areas in the country. The inspection chief in each area is directly responsible to the state government for setting up a mine safety and health inspection agency [6,9]. The organization of the MSHA is shown in Figure 6. The United States has established a vertical coal mine safety supervision system and set up a rotation-type supervisory

personnel system. Local safety inspectors are not allowed to participate in the investigation and handling of more than three fatal accidents in their jurisdiction. The United States has established a system that can effectively prevent inspectors and mine owners, local governments form a mechanism of common interest and alliance.

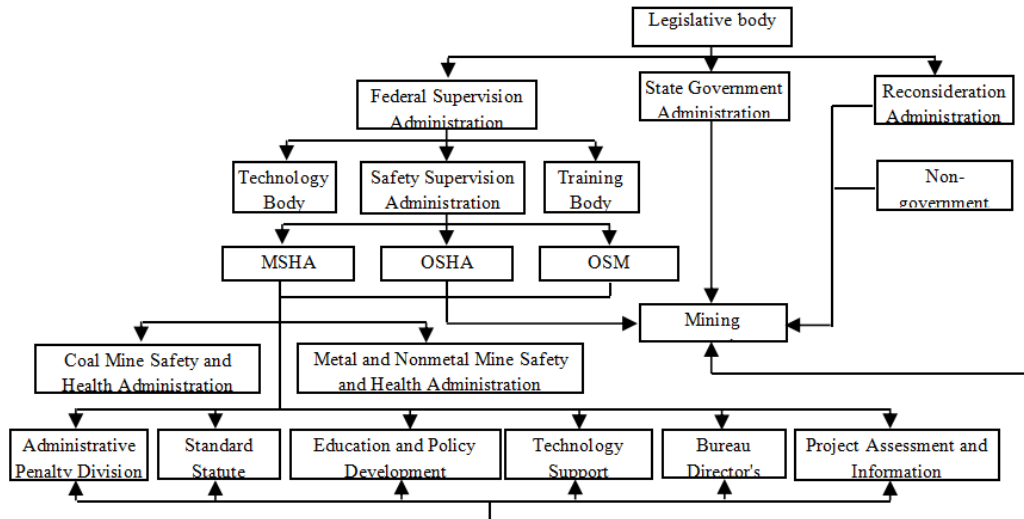


Figure 6. The framework map of MSHA of US.

MSHA main job responsibilities include [10,11]. allegations of miners danger, allegations of knowingly or deliberately (criminal) offenses by miners, the development and strengthening of safety and health standards, the assessment and imposition of civil penalties for violations of mine safety and health standards, the assessment of mine operators' Planning and education and training programs. High-quality training to inspectors, technical support staff and coal miners. Approval and certification of mechanical and electrical products used in underground coal mines and gas mines to ensure that these products will not cause a fire or explosion. Provision of technical assistance to improve their education and training. Work with states to develop mine safety and health programs. Funding provision to the mining state

and oversee rescue and recovery operations. China established the State Administration of Work.

Safety (at the ministerial level) in 2005 and the State Administration of Coal Mine Safety (deputy ministerial level) at the same time, the Ministry of Emergency Management of the People's Republic of China was established in 2008. It has established a coal mine supervision system that combines comprehensive supervision with special (industrial) regulation, a combination of state supervision and local supervision, and a combination of government supervision and other supervision. There are 27 provincial coal mine safety supervision bureaus and 76 inspection branch throughout the country, with nearly 3000 supervisors) Coal mine safety supervision system is shown in Figure 7 [1,12].

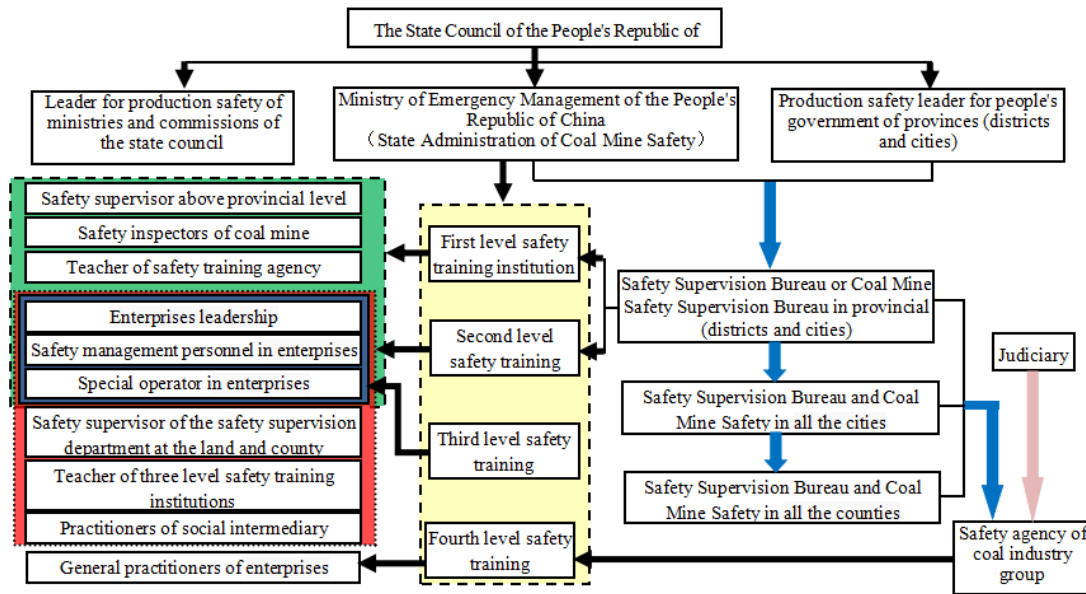


Figure 7. The safety supervision and training system of coal mine in China.

The establishment and improvement of China’s coal mine safety supervision and training system have played a supervisory and promotional role in the work of coal mine safety in the country, which has played a significant role in promoting organization, publicity, politics and law, law enforcement, organization establishment, staff training and technological progress.

3.3. Comparison Trade Union Comparison

In the US, there are many non-governmental organizations involved in safeguarding the rights and interests of miners [9,13]. More than half of the miners have taken part in various trade union organizations. The unions have a high degree of independence. The most important of these is the UMWA, and nearly half of the miners are members of the UMWA. As a miner’s rights protection organization, UNWA acts in parallel with the legislative, judicial and administrative departments under state power. Its focus is on collective bargaining with employers in improving employee working conditions (and) improving benefits and wages. Trade unions also played a significant role in formulating laws on safety and health. After each major accident, coal miners, through trade unions, promoted the federal government and the state governments to make laws and regulations on improving the safety and health of coal mines. 2006 Sago coal mine accident prompted the United States to issue a “coal mine improvement and new emergency response law”, Trade unions have better safety systems and members are not to be dismissed or cracked without fear of reporting.

China has the largest trade union organization in the world and is better adapted to changes in society [9,14]. China has also won the rights and interests of workers to a large extent through legislation, supervision and cooperation. But there are still many problems, the Chinese trade unions are subject to the dual leadership of the Communist Party committees at the same level and the

unions at higher levels, This top-down structure, focuses on the implementation of higher-level policies, so that trade unions cannot really represent the interests of miners. The independence of trade unions is relatively poor, and various activities of trade unions must take into account the interests of the state, society and enterprises, and weaken the maintenance of the interests of the workers. The rights and interests of miners have not been reflected and emphasized in the relevant normative legislation for negotiating and negotiating with the owners, which has weakened the collective power of the miners (the strike cannot be organized freely). The measures often used in the work of trade unions place greater emphasis on the government’s position, usually through administrative means to coordinate, intervene and negotiate. Because miners are afraid to be dismissed or dealt with internally, their own legal awareness is weak. Therefore, their enthusiasm for joining trade unions is not high, and awareness of rights protection (reporting) is even less strong.

3.4. Comparison Education and Training

Experiences from coal mine accident investigations in the US show that 85% of coal mine accidents are caused by workers’ unsafe behavior. In China, coal mines cause as much as 65% or more of accidents because of “three violations” of workers. The survey of coal mine accidents in the United States leads to the conclusion that “monitoring is important and training is more important than monitoring” [14,15].

The US federal regulations “mineral resources volume” stipulates that all workers (including employers and managers) must have compulsory health and safety education. New workers can only work independently after half a year’s practice, and then undergo retraining every year. For those who do not receive safety training according to the regulations, they must not engage in coal mine work. If they are found to be undocumented, they

will not only leave their posts, but also punish the operators. At the same time, mine safety inspectors are also required to be trained. Mine safety inspectors must have over 5 years of actual mining experience and be trained at the National Institute of Mine Health and Safety. According to the level and needs of mine safety inspectors, they are respectively given primary training, advanced training and regular training. The qualification of the training teachers is carried out, and a rigorous assessment, inspection system and dismissal procedure are also provided for the qualified training teachers.

At present, there are more than 1000 coal mine safety training institutions at all levels in China. Although the safety training work has made great progress, there are still many problems. The awareness of safety training and education by enterprises and employees is not in place, which leads to the safety training in the form of reality. The system of training and assessment at all levels is not perfect), there are “heavy process, light results” and even “Training Specialist” alternative training. The training teacher strength is thin, the way is monotonous, the content is dull and repetitive, and the training effect lacks the safeguard.

3.5. Comparison Natural Conditions Comparison

The proportion of open-pit mines is about 70% in the United States [16]. The geological structure of coal seams is simple. Most of them are gently inclined or near-horizontal coal seams. It is low that geological factors affect coal mining safety and the gas in coal seams content. However more than 96% of China’s coal mines are underground mining, the geological conditions are complex and varied, and the coal seam conditions are poor [17,18]. High-gas mines, coal and gas outburst mines make up about 30% of the total number of mines that are produced, and 60-70% of mines are mined in complex and extremely complex structural conditions.

3.6. Comparison Accident Investigation

The survey of coal mine accidents is different in many aspects such as accident investigation concept, accident investigation team members, accident classification investigation, investigation deadlines and accident reports in China and US, as shown in Table 4 [19-21].

Table 4. The comparison of accident investigation in coal mine between China and the US.

Contrast	US	China
Investigation concept	Focus on the cause of the accident analysis and lessons learned	Investigate and rectify the cause of the accident, pay attention to the identification of responsibility and accountability. The description of the direct and indirect causes of the accident is relatively general and simple, and lacks the analysis of the underlying causes of the accident.
Investigation team members	The accident investigation team is generally composed of three relatively independent investigation teams including the federal government, state government and trade union organization, each with a different composition. The investigation team may employ experts to participate in the investigation. (To the maximum extent to ensure the comprehensiveness, objectivity and fairness of the accident investigation)	The coal mine safety supervision agency shall take the lead and shall be composed of the local people’s government, the work safety supervision and administration department, the department responsible for the safety supervision of coal mine, supervision, policemen and trade unions, and invite the peoples’ procurator rate to send people to participate. The investigation group has three groups of technology, management and synthesis, which can invite relevant experts to participate in the investigation. (It is impossible for departments to strictly protect interest avoidance and make the investigation lack of objective neutrality. Technical investigation and judicial investigation are combined. The interference of various human factors often prevents the thorough and comprehensive investigation.)
Hierarchical survey	Dead 3 and above, it is organized by the Director, MSHA Mine Safety and Health Surveillance Division; Dead no more than 3, it is organized by the director of district surveillance division	Depending on the level of accident, led by different levels of government.
Investigation period	There are on strict deadline for investigation (thorough investigation of technical and management issues for accidents) and some investigation may take up to a year (sago mine accident)	The accident investigation report shall be submitted within 60 days after the accident, and the longest report shall not exceed 120 days .(in-depth, thorough and objective analysis cannot be conducted on the technical, management and institutional factors of accident)
Investigation report	Online public, anyone can access (can play a role in preventing accident)	Rarely open to the public, access difficulties (warning education is not strong)

4. Inspiration

Through the comparison and analysis of the coal mine safety of China and the United States, which can draw on the experience of the US coal mine safety and get the following inspiration.

(1) Further develop a perfect system of coal mine safety regulations. The long-term system of coal mine safety regulation should be established to ensure the continuity and deterrence of the laws and regulations implementation. To clarify the position of the party and government organs,

social groups, markets, enterprises and miners in the safety of production. Rationalize the relationship between power and responsibility among different departments in the party and government, establishing the responsibility system of “party and government have common responsibilities, one post has two responsibilities, and make concerted efforts”. Which should strengthen the supervision of the power organs on the safety in production.

(2) Intensify the law enforcement of coal mine safety supervision, further strengthen the supervision and

independence of the supervision departments, and increase the supervision and restriction on the organs of authorities. The authority should improve the transparency and impartiality of the law enforcement.

(3) Strengthen the organization and coordination of trade unions. Miners should improve rights (illegal reporting) awareness, they don't have to worry about getting dismissed or attacked because of reports.

(4) Strengthen the construction of training teachers and select teachers with high theoretical level and rich practical experience. Improve the education and training operation mechanism, strengthen the management of the teaching process. Establish a personnel training archive system, ensure the quality of teaching and evaluate the training effectiveness so as to avoid the training becoming a mere formality. Strengthen the training of safety supervisors at all levels and improve their safety supervision and technical operational capabilities.

(5) Improve the accident investigation concept, ensure the independence of the investigation work, clarify the division of responsibilities of the investigation team, use advanced accident investigation techniques and methods to establish an internal investigation mechanism of the inspectors.

(6) China should orderly shutdown coal mines that have high danger of outburst of coal and gas, have serious natural arson or have complicated hydro geological conditions, and other arduous mining conditions.

Acknowledgments

This work was supported by "National Natural Science Foundation of China (51774116, U1504403)", "Scientific and Technological Project of Department of Science & Technology of Henan Province (182102210320)" and "Postdoctoral Research Fund of Henan Province (2017)". In the study process, the authors are also grateful to Professor Mingju Liu of Henan Polytechnic University for his ardent guidance and help.

References

- [1] Wang Xianzheng. *Practices of coal mine safety and health inspection in US*. China Coal Industry Publishing House: Beijing, 2001.
- [2] Deng Qigen, Wang Yan, Liu Mingju, et al. Statistic analysis and enlightenment on coal mine accident of China from 2001-2013 periods. *Coal Technology*, **2014**, 33(9): 74-76.
- [3] Kniesner T.J., Leeth J.D. Data Mining Mining Data: MSHA Enforcement Efforts, Underground Coal Mine Safety, and New Health Policy Implications. *Journal of Risk & Uncertainty*, **2004**, 29(2): 83-111.
- [4] Saleh J.H., Cummings A.M. Safety in the mining industry and the unfinished legacy of mining accidents: Safety levers and defense-in-depth for addressing mining hazards. *Safety Science*, **2011**, 49(6): 764-777.
- [5] Jing Guoxun. Analysis on the law of mine gas accident in China from 2008-2013. *Journal of Safety and Environment*, **2014**, 14(5): 353-356.
- [6] Zhao Jun, Li quanming, Wang Yunhai. Comparative analysis on coal safety production laws system of China to US. *Journal of Safety Science and Technology*, **2008**, 4(4): 82-85.
- [7] Poplin G.S., Miller H.B., Ranger-Moore J., et al. International evaluation of injury rates in coal mining: A comparison of risk and compliance-based regulatory approaches. *Safety Science*, **2008**, 46(8): 1196-1204.
- [8] Huang Gang. Chinese and foreign coal mine safety supervision mode comparative analysis and some suggestions. *Journal of Safety Science and Technology*, **2013**, 9(4): 156-160.
- [9] Li Xinjuan. Comparison and analysis of the mechanism of coal mine safety management in China and US. *Mining Safety & Environmental Protection*, **2012**, 39(5): 93-96.
- [10] Homer A.W. Coal Mine Safety Regulation in China and the USA. *Journal of Contemporary Asia*, **2009**, 39(3): 424-439.
- [11] Knott J.H., Rich R.F. The politics of health and social welfare in the United States. *Ageing International*, **2006**, 31(2): 96-117.
- [12] Feng Qun, Chen Hong. The safety-level gap between China and the US in view of the interaction between coal production and safety management. *Safety Science*, **2013**, 54(4): 80-86.
- [13] Bise C.J, Peck K.L. Microcomputer-based instruction for miner safety-training programs. *Computers & Industrial Engineering*, **1991**, 21(1-4): 413-417.
- [14] Chen Hong, Feng Qun, Long Ru-yin, et al. Focusing on coal miners' occupational disease issues: A comparative analysis between China and the United States. *Safety Science*, **2013**, 51(1): 217-222.
- [15] Esterhuizen G.S., Gürtunca D.R.G. Coal mine safety achievements in the USA and the contribution of NIOSH research. *Journal of the South African Institute of Mining & Metallurgy*, **2006**, 106(12): 813-820.
- [16] Li Dasheng. Comparative research into the situation of coal mine safety at home and abroad. *China Mining Magazine*, **2015**, 24(8): 45-48.
- [17] Nie Baisheng, Huang Xin, Xue Fei, et al. Comparison and forecast of coal mine safety production level in China and US. *Safety in Coal Mines*, **2017**, 48(04): 234-237.
- [18] Deng Qigen, Zhang Sai, Liu Mingju. Causes and advices for improvement of coal mine safety situation in China 2006-2015. *Coal Engineering*, **2016**, 48(12): 99-102.
- [19] Hickman J.S, Geller E.S. A safety self-management intervention for mining operations. *Journal of Safety Research*, **2003**, 34(3): 299-308.
- [20] Liu Lu. The comparative analysis of the coal mine accident investigation system between China and US. *China coal*, **2014**, 40(6): 132-134.
- [21] Ren Guoyou. Comparative analysis of occupational safety and health act in China and US. *China Safety Science Journal*, **2009**, 19(7): 46-51