MSc Thesis

An Analysis of Unsafe Acts of

Coal Mine Rescue Accidents

Yuanchi XIANG

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School of Resources and Safey Engineering
China university of mining and technology

Beijing, Haidian district, Xueyuan road, ding 11
Zonghe Building 404
Phone: +86 18612461869
xiangyuanchi@yahoo.com

Declaration of Authorship

„I declare in lieu of oath that this thesis is entirely my own work except where otherwise indicated. The presence of quoted or paraphrased material has been clearly signaled and all sources have been referred. The thesis has not been submitted for a degree at any other institution and has not been published yet."

Abstract

Coal mine rescue operation conditions are complex and gathering all kinds of risk factors, which is prone to make accidents. The study of unsafe acts is very important on the prevention of coal mine accidents caused by rescue. In this thesis, through data collection, the coal mine rescue accidents' sample library established has 69 accidents from 1981 to 2011, and these accidents are analyzed from time, death toll, location and ownership. This thesis focuses on direct unsafe act and high-frequency unsafe acts which lead to coal mine rescue accidents, as well as the cause of unsafe condition. Conclusions are drawn. In 69 coal mine rescue accidents, casualties of rescuers are mostly from 3 to 10. Coal mine rescue accidents mostly happen in following seven locations: mining return air stone door, coal face, gob, transit haulage way, contact lane, fire dam, driving lane and occupying a total of 82.61%. Most coal mine rescue accidents happen in state-owned coal mines. There are five categories of direct unsafe acts which cause coal mine rescue accidents：Not wearing respirators as required, not following the requirement of gas detection, the rescue crew poor ability, technical measures not in place and violation commanding. It preliminary explores unsafe acts and their causes in mine rescue accidents to help safety workers and rescue organization to prevent and control mine rescue accidents.

Keyword:

coal mines, rescue accidents, samples, distribution analysis, unsafe acts

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1 Introduction

This thesis studies unsafe acts of coal mine rescue accident, as well as their causes and the relationship between them.

1.1 Research Background and Significance

Coal mine safety production is one of the country's key accidents to control. Coal mine emergency rescue is an important part of the national emergency management of accidents and disasters ("Coal Mine Emergency Rescue Series" Editorial Board, 2008). As one of the most common forms of accidents in coal mines, rescue accidents in coal mines are the types of accidents that occur when rescue workers start rescue operations after a coal mine accident occurs, resulting in the death of rescue workers or the further expansion of accidents.

As the backbone of coal mine emergency rescue and protection, coal mine rescue teams play an important role in the process of mine rescue and disaster relief (Henan Administration of Coal Mine Safety, 2012). The geological conditions in our country are complex. Coupled with the varying degrees of safety management in various mines and the uneven staffing quality, the difficulty of emergency rescue operations will increase in the coal mine accident. Due to the complex rescue conditions and the underground environment, as well as the problems existing in the coal mine rescue team itself, it often happens that in the process of coal mine rescue, the rescuers themselves have died or led to the destructive expansion of accidents. According to incomplete statistics of existing data, nearly 280 coal mine rescue accidents have occurred since the founding of the People's Republic of China, and nearly 700 rescue workers have died (Tian Weidong, 2010). Summing up the lessons learned from coal mine rescue accidents, in-depth analysis of the causes and taking effective measures, are the main means to reduce coal mine rescue accidents and realize coal mine rescue.

Coal mine rescue operations are complex and various risk factors are gathered and are prone to accidents. Coal mine rescue is a comprehensive operation process. The analysis and prevention of coal mine rescue accidents involve various aspects. Safety management, safety system engineering, safety ergonomics, organizational behavior,

accident theory and other knowledge need to be applied to comprehensively analyze various factors that cause coal mine rescue accidents (Lan Zequan, et al., 2016)

Causes of coal mine rescue accidents include objective factors such as the backwardness of rescue technology and rescue equipment (Wang Libing,2014). Among them, the subjective human factor is the main cause of coal mine rescue accidents (Chen Xiong, 2007). Therefore, a comprehensive analysis of coal mine rescue accidents over the years, to know various causes with behavioral science theory and how to reduce the control of factors in the actual rescue process is an important measure to reduce this kind of accidents.

As a manifestation of coal mine secondary accidents, the study of coal mine rescue accidents is of great significance for improving the overall safety level of coal mines and effectively reducing deaths and losses in the rescue process. This thesis analyzes the causes of coal mine rescue accident and can use the scientific methods of behavioral safety to deeply analyze the mechanism of accidents. This can reduce the occurrence of coal mine rescue accidents. At the same time, it also provides reference for the future coal mine rescue work and the construction of coal mine rescue system.

1.2 Research Status of Coal Mine Rescue Accidents

In the coal mine rescue mechanism, scholar Amy et al. (2001) analyzed the coal mine rescue system and constructed a framework for the emergency rescue mechanism for coal mines. The framework of the mechanism comprehensively considers the policies, plans, and capabilities of the rescue organizations and functional departments at all levels, and can effectively use the resources at all levels of the coal mine rescue. Josefa (2004) used computer programming techniques to establish a simulation model of a mine rescue system.

In the research and development of aid decision-making systems for coal mine rescue operations, LEVY Jason.K (2017) and other scholars designed and developed a GANP rescue decision support system to solve the problem of lagging rescue information when it affects the decision-making of coal mine rescue. The system can effectively plan coal mine rescue information and assist coal mine rescue commanders and decision makers in making accurate and rapid decisions. Scholars K. N. Papamichail (2005) and others have developed RODOS online decision support

system when they are deeply studying nuclear rescue accidents. The system is a long-range aided decision-making system, and it is successfully introduced into the practice of coal mine rescue. J. L. Wybo (1998) re-programmed the operation mechanism of the original command and decision support system for coal mine emergency rescue, expanded the key technologies and concepts of mine rescue in the original system, and effectively analyzed the details of the mine rescue decision-making process. F. J. Milliken et al. (1987) focused on the ambiguity and uncertainty of the information in the coal mine rescue process, and conducted in-depth analysis of the impact of system engineering and fuzzy mathematics on the effectiveness of fuzzy information on coal mine rescue.

In the study of coal mine rescue management system, after years of practical tests and repeated verification, the rescue system has matured (Sanjay Jain, 2005). U.S. mine rescue has two major systems: (1) Rescue organizations under the supervision and control of the government, all members of the group and organization are full-time professionals with rich practical experience and capable of responding to all kinds of unexpected rescue missions; (2) Private voluntary mine rescue organizations, members are generally part-time, whose rescue capability is relatively weak but flexible (Kweku-Muata, 2002). Australia's coal mine rescue system is divided into three levels. The functions, responsibilities and plans at all levels are independent, and the self-help mode under unified management is implemented (Lee D. Han, 2006). The coal mine rescue system in the UK is a "1+1" model, in which coal mine rescue organizations and coal mine enterprises sign rescue cooperation agreements and adopt a paid rescue approach (Stefan, 2004). Ukrainian coal mine rescue organizations are organized and managed by the government, implementing militarized management (Daniel, 2005). At the same time, rescue depots set up sub-stations, which can be used to respond to evacuation tasks.

At present, Chinese scholars' research on coal mine rescue accidents mainly focuses on the following aspects: the application of rescue equipment and facilities; the construction of rescue teams; the analysis of coal mine rescue accidents; and the development of emergency response command procedures.

In the construction of mine rescue teams. Scholars Li Shouzhao (2007) and others discussed the plan and path for building a mine rescue team, and four measures have been proposed to comprehensively improve the rescue capability. Yang Daming (2002) analyzed the problems and deficiencies in the construction of the mine rescue

team and attributed the mine rescue accident to: irrational establishment of rescue organization; not propose a feasible rescue system with coordination; poor rescue equipment; inadequate training of the rescue team; lacking funds; and lagging behind information communication.

In the daily management of the mine rescue team. Bie Xinfeng et al. (2007) pointed out that the main drawbacks of China's existing coal mine rescue system through field research and exploration. On this basis, Wang Bin (2012) proposed improving the management of the rescue system, including preparation and review of preplans, intensified drills, increased supervision, and gradual realization of rescue areas to increase coal mine rescue capabilities.

In the study of mine rescue accident reasons. Ni Maolong (2014) and others analyzed the rescue accident and concluded that the main cause is misconduct. Wang Qingyi (2013) regards equipment is the main cause. Zhao Yueyue (2009) believes that violation behavior, including not carrying relevant equipment, not using correct signals in the rescue process, insufficient risk assessment, and violation of the "rescue procedures" are the main causes. Liu Pengxiang (2013) highlighted the poor self-protection capabilities of rescue workers.

In the research on coal mine rescue equipment and technology. Dong Debiao and others (2006) believe that the main factors are: individual protection technologies and equipment, disaster relief technologies and equipment, command communication systems, rescue dispatch and resource allocation, follow-up analysis and training of accidents. Kong Qinglin (2009) through the analysis of coal mine rescue accidents, explored the factors that easily lead to coal mine rescue accidents and the mutual influence among them, and provided reference for the improvement of mine rescue ability.

In the analysis of the factors affecting the coal mine rescue effect. Cai Wenfang (2004) statistically analyzed the intrinsic and external factors affecting the coal mine rescue. Ke LiJi (2014) proposed the important psychological indicators affecting the implementation of the safety behaviors of rescue workers by exploring the operating environment and working pattern characteristics of coal mine rescue personnel.

China's research on the rescue of coal mines is relatively diversified. There are both researches on the rescue system of coal mines, as well as research on specific coal mine rescue equipment and technology, and factors affecting the rescue of coal

mines. There is research on existing technologies as well as research on systems and management.

1.3 Theoretical Basis

1.3.1 Behavior-based Safety "2-4"Model (24Model)

The theoretical basis of this thesis is 24Model (Fu Gui, 2016) ,which is a modern accident-causation chain model. It analyzes the causes of accidents based on human behavior. The analysis is convenient and significant. In the analysis of coal mine accidents, 24Model can analyze the four causes of the coal mine rescue accidents as follows: direct cause, indirect cause, radical cause and root cause. The complete model is shown in figure 1.
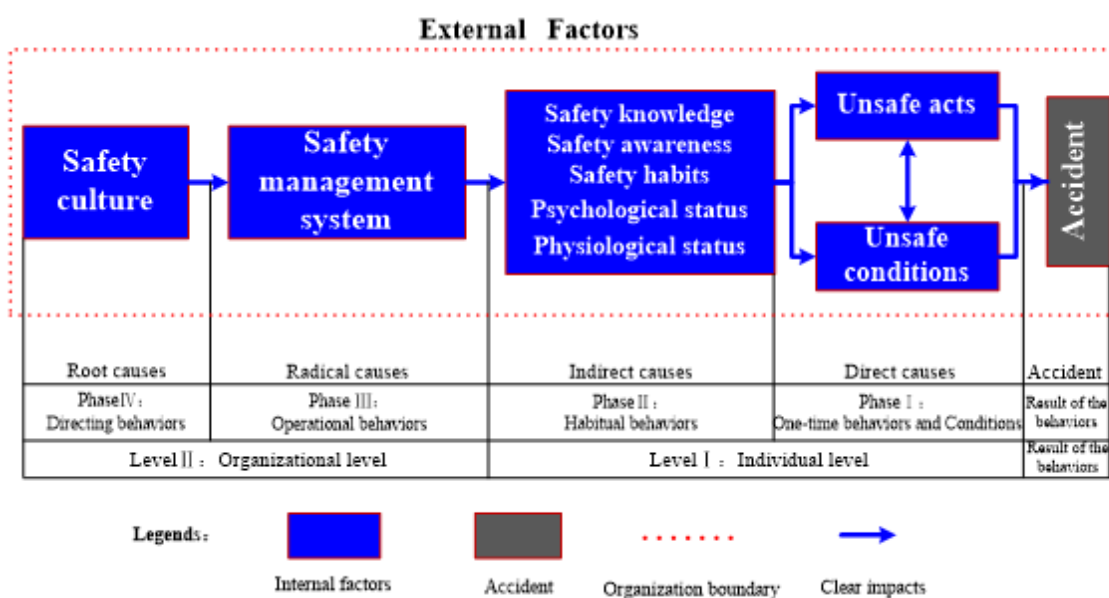
Figure 1: 24Model (Fu Gui, 2016)

The "2" in 24 Model refers to the accidents are divided into two levels of organization and individual, "4" refers to the four stages of behavioral development process-guidance, operation, habitual, one-time (Fu Gui, 2013). The guiding behavior of safety culture (root cause) guides the operation behavior of the safety management system (radical cause), and indirectly leads to the individual's habitual behavior (indirect cause), thereby causing the injurer to make a one-time unsafe act in an accident (direct cause) eventually led to the accident.

1.3.2 Application in Accident Analysis

Behavior-based safety believes that accidents are the result of the operation of the behavior chain. The main purpose of safety work is to prevent accidents, and it is necessary to control every link of the behavior chain (Komaki,1978; Krause 1999). 24Model is a modern accident causal chain based on behavior-based safety theory, as well as the Heinrich accident cause chain (1980) and the Reason Swiss cheese model (1990). The cause chain of behavioral-based safety accidents has at least the following 5 uses: (1) Give the method and technical route for accident analysis; (2) Give the results of the accident analysis; (3) The basis for the division of accident liability; (4) The basis for the formulation of accident prevention strategies; (5) The method of safety supervision.

The starting point of the 24Model is an accident. This article is based on its ideas, taking coal mine rescue accidents as the starting point to analyze the causes of coal mine rescue accidents. It concretizes indirect causes, radical cause and root cause, and establishes the radical cause of coal mine rescue accidents and the reciprocal relationship between safety management systems, radical causes, and safety culture. It enables people to clearly see the specific relationship between safety management system, safety culture and coal mine rescue accidents. At the same time, 24Model can also link the personal behaviors of rescue personnel with rescue organization behavior (mine rescue management system and mechanism), so that the analysis of the causes of coal mine rescue accidents is clear and comprehensive and reliable.

1.4 Research Content and Research Methods

Taking accidents as the starting point is an important means for safety management. The research on the case analysis of coal mine rescue accidents is a direct method to study the causes of coal mine rescue accidents. This thesis screens various types of coal mine rescue accidents that have occurred since the founding of the People's Republic of China. Through the use of 24 Model, it conducts in-depth analysis and research on the coal mine rescue accidents, and uses mathematical methods for statistics and classification to discuss the causes. The main research content is as follows:

(1) The establishment of a sample database for coal mine rescue accidents.

Firstly, through the national coal mine analysis report compiled by the State Administration of Coal Mine Safety and the China Coal Industry Yearbook, as well as other channels, such as news, newspapers, etc., to make a comprehensive and systematic collection of coal mine rescue accidents. Second, when screening samples of coal mine rescue accidents, three principles should be followed: comprehensiveness of description, seriousness of accidents, and typical accidents.

(2) Analysis of coal mine rescue accident sample library.

In order to understand in detail the law of occurrence of coal mine rescue accidents, four aspects will be separately analyzed for coal mine rescue accidents, namely, the distribution of number of deaths, place of occurrence, type of occurrence, and ownership of enterprises. Exploring the general laws of accidents in coal mines.

(3) Unsafe acts and analysis of their causes.

According to 24Model, the analysis of this step focuses on the statistical analysis of the unsafe acts of the rescue workers and the establishment of an unsafe act library for rescue accidents in coal mines. Then classify unsafe according to the type of work environment, accident type, time series, etc. On this basis, the causes of unsafe acts are analyzed, which are the causes of habitual behavior (safety knowledge, safety awareness, and safety habits). Direct unsafe acts and high-frequency unsafe acts in coal mine rescue accidents are identified.

(4) Measures to control and prevent coal mine rescue accidents

On the basis of cause analysis of unsafe acts in coal mine rescue accidents, related measures have been put forward for rescue teams and mine organizations to control and prevent rescue accidents.

In this thesis, a variety of analysis methods are used to analyze the unsafe acts of coal mine rescue accidents, as well as rescue systems (organizations) and rescue mechanisms. They are literature review method, case analysis method, comparative analysis method and 24Model analysis method. The general law and the reasons for their occurrence have been derived.

2 Establishment of Coal Mine Rescue Accident Sample Library

This thesis studies how to establish a coal mine accident rescue sample library. Definition of a coal mine rescue accident is defined by environmental characteristics, main participants and the consequences of an accident. Samples of coal mine rescue accidents are selected from four main Chinese authoritative sources. Comprehensive description, severity, time are three principles to filt cases.

2.1 Definition of Coal Mine Rescue Accidents

Coal mine rescue accident is the accident occurs under the condition of coal mine disaster and in the rescue process by rescue workers. It is slightly different from general industrial accident, because coal mine rescue accident happens when dealing with the accident (Wei J., Zhi-ming Z., Yuan-chi X,2016).

After reading the information and documents in China and abroad, there is no related definition of coal mine rescue accident has been found. But the definition itself would impact the sample statistics of coal mine rescue accidents. So, first of all, the definition or characteristics of coal mine rescue accident need to be clarified. These unified and clear standards will benefit to establish coal mine rescue accident sample library.

Combining the definition of the accident we can know, we need to sort out three aspects to clarify the definition of coal mine rescue accident. They are environmental characteristics of coal mine rescue accident, main participants of accident and the consequences of an accident. The following will elaborate the contents of the above three aspects.

Environmental characteristics of coal mine rescue accident: coal mine rescue accident takes place in the process of coal mine disaster disposing. So it is the accident in dealing with the accident, also a specific form of secondary coal mine accident. This environmental feature limits the foundation of coal mine rescue accident.

The main participants in coal mine rescue accident are followings. Command body of coal mine rescue accident is mine emergency rescue headquarters or other mine rescue command staff. Action body is mine rescue team. Besides them are assistant

mine rescue team members and others involved in the mine rescue, like coal mine workers who cooperate to rescue. From these main participants in coal mine rescue accident, generate body of unsafe acts and trigger body of unsafe conditions can be limited.

Consequences caused by coal mine rescue accident. Like other accidents, coal mine rescue accident is accident which must have its impact. Taken together, coal mine rescue accident mainly causes three consequences. The first is causing casualties of rescue workers themselves. The second is causing further injury to other people. The third is causing further expansion of the accident though no casualty, such as increasing losses and destructiveness. The nature of these three aspects are same, which is causing further expansion of the accident.

Through the preliminary analysis of above three aspects, this paper gives a primary definition of coal mine rescue accident. Coal mine rescue accident is the incident which occurs in the process of coal mine rescue crew disposing disaster or accident, and it will result in further expansion of the accident. The consequences include casualties of rescue workers and other people, as well as further destructiveness. With such a preliminary definition, there will be a basis of coal mine rescue accident samples selection. It will facilitate the establishment of sample library.

2.2　Source, Selection and Establish of Samples

2.2.1　Source

Sample source of accident reflects the accident's authority, and it will also directly affect the accuracy and applicability of the analysis results. Sample source of coal mine rescue accidents in this thesis has four main aspects.

(1) "National Coal Mine Accident Analysis Report Collection." It uniformly sorts out the coal mine accidents annually, covering most typical and influential accidents.

(2) "China Coal Mine Accident and Expert Comments Set." According to the type, 12 categories of coal mine accidents are counted. It covers a large number of typical coal mine accidents occurred from 1949 to 1995, as well as some analysis and comments.

(3) China Coal Yearbook. It makes a comprehensive summary of incidents in coal industry, which contains all submitted coal mine accidents.

(4) Other routes. They include State Administration of Work Safety's official website, coal-related journals and websites, news and information related to coal mine accidents. These materialsare complementary to official information, usually reflect the actual situation from all angles.

These are the four major sources of coal mine rescue accidents in this chapter. The number of coal mine accidents is huge. So above information complement and prove each other to restore the actual situation. And a comprehensive collection of coal mine rescue accidents can provide the basis for establishing sample library and accident analysis.

2.2.2 Principles of selection

Due to the big number of coal mine accidents, it will face great difficulties to collect coal mine rescue accidents in such a big time span and numerous materials. Accident statistics themselves are to analyze the specific cause of such accidents, in order to formulate appropriate measures to prevent accidents. Based on this,this paper decides the selection principle of coal mine rescue accidents, and establishes the sample database on this basis. When screening the samples, there are three principles of accidents: comprehensive description, severity, time.

First, the principle of comprehensiveness. Comprehensive description of the accident means that an accident described in reference need to be as detailed as possible, and it can clearly convey the whole process and all information in various stages (personnel assignment, specific processing procedures, problems faced during the rescue, response during the rescue of each organization). Only information described in detail and specific, accident can be analyzed effectively and comprehensively. What need to be completed about accident include: type, level, organization, time, place, death toll, loss, size of enterprise, ownership, legitimacy of operating activities, description of the accidentin detail. With the above elements, an accident can be chosen into the sample library.

Second, the principle of severity. Complying with the principle of the severity is the accident chosen need to have some serious social impact and destructiveness. Through the early stages of statistical samples, coal mine rescue accidents usually occur in major, serious or destroyed accidents. In accidents with general level, there is no coal mine rescue accident or just small accident with low severity (such as 1 to 2

minor injuries). Therefore, in the sample library establishment of coal mine rescue accidents, whose level is major or above should be considered. Thus, not only workload can be reduced, but also the occurrence regularity can be reflected objectively.

Third, the principle of last time. It means when establishing the sample library, occurrence time should be considered. Usually over time,techniques and equipment of mine rescue are regularly updated which affect the occurrence. In the early stages of case statistics and analysis, we found that the techniques and equipment from 1949 to 1965 have been abandoned. Compared with present, from organizational forms to rescue techniques and equipment have a certain of differences. Therefore, this paper chose coal mine rescue accidents as close as possible in the time dimension. New accidents can reflect the actual situation, and can be analyzed to get favorable measures and universal laws.

2.2.3 Samples

Within the range of coal mine rescue accident data, this paper selects69 accidents from 1981 to 2011.These accidents' levels are major, serious or destroyed (general accidents are not considered). These accidents widely cover different occurrence types of mine rescue accidents, such as gas explosions, flooding, fire, etc. They also widely include state-owned key coal mines, state-owned local coal mines and township coal mines. Besides, the development of coal mine rescue technology in this period is relatively stable. The specific sample library is table1 in appendix.

3 Overall Analysis of Samples

For a detailed understanding of the occurrence law of coal mine rescue accidents, separate analysis are done from following four aspects. They are the distributions of: death toll, location, type and enterprise's ownership.

3.1 Death Toll Distribution

The death toll is one of the most intuitive measure of coal mine rescue accidents, whose distribution reflects the overall laws. In this paper, 69 accidents from earlier statistics are sorted according to the occurrence year. The number of annual deaths and occurrence are as shown in Table 1.

Table 1: The number of deaths in coal mine rescue accidents

Particular year	Death toll / person	Number of accidents / incidents	Particular year	Death toll / person	Number of accidents / incidents
1981	15	3	1997	8	3
1982	10	5	1998	14	3
1983	13	2	1999	16	2
1984	7	2	2000	6	2
1986	4	2	2002	2	1
1987	17	4	2004	30	2
1989	6	3	2005	7	2
1990	25	5	2006	11	2
1991	7	3	2007	5	1
1992	3	1	2008	4	2
1993	12	4	2009	3	1
1994	22	4	2010	11	3
1995	36	5	2011	3	1

1996	3	1	
Total deaths	300	Total number	69

As can be seen from figure 1 that from 1981 to 2011, the number of deaths and occurrence showed a fluctuation drop. A total number of 69 accidents and the death toll is 300, with a positive correlation in fluctuations law. There are several peaks when entirety was declining: In 1987, 4 accidents, 17 deaths; In 1990, 5 accidents, 25 deaths; In 1995, 5 accidents, 36 deaths; In 1999, 2 accidents, 16 deaths; In 2004, 2 accidents, 30 deaths. These five years are the mutation and mutation appearing in the overall trend. Among them, there are the maximum numbers of deaths and occurrence.
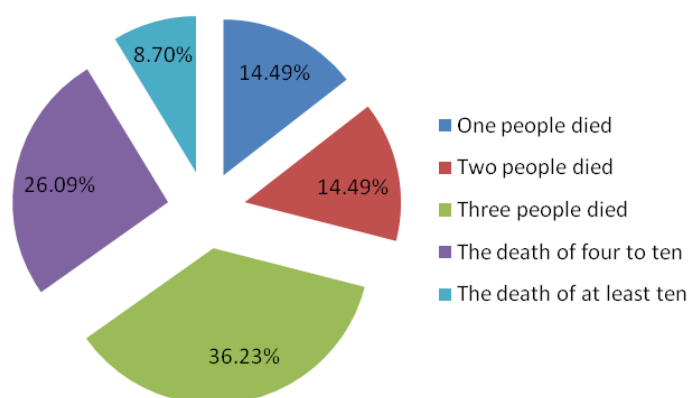

Figure 2: Percentages of accidents with different casualties

As can be seen from figure 2, accidents with 3 deaths account for the most of all accidents, 25 cases (36.23%). The second are 18 accidents (26.09%) with 4- 10 people dead. After that are accidents with 1 death and 2 deaths, which each takes 10 times (14.49%). At least 5 accidents have over 10 deaths, accounting for 8.7%.

Although the proportion of coal mine rescue accidents with over 10 deaths is relatively small, the impact is huge. These five accidents are as follows: (1) 1983-09-11, Fengcheng Mining Bureau, Jiangxi, Pinghu Coal Mine Gas Explosion, 11 rescuers dead; (2) 1994-02-12, Xuzhou, Jiangsu, Yian Mine Fire, 14 rescuers dead; (3) 1990-05-08, Jixi Mining Bureau, Heilongjiang, Xiaohengshan Mine Fire, 12 rescuers dead; (4) 1995-12-31, Panjiang Mining Bureau, Guizhou, Laowuji Mine Gas Explosion, 12 rescuers dead; (5) 2004-08-26, Yuncheng Hejin,Shanxi, Xiaowangou Coal Mine Gas Explosion, 28 rescuers dead.

The above analysis shows that: coal mine rescue accidents occurred in China, always have 3-20 casualties of rescuers, accounting for up to 62.32%. Accidents with more than 10 deaths have a certain proportion, but it is relatively small.To control the casualties caused by coal mine rescue accidents, it is necessary to control more with

the bigger ones. People should gain experience from these accidents and summarizeup the shortcomings, which can significantly reduce casualties.

3.2 Location Distribution

The distribution of accident's places reflects the intrinsic properties of the accident's objective environment. Specific to coal mine rescue accidents, analysis of these accidents' site distribution can effectively know the accident-prone points. It will help to analyze the underlying causes and conditions, and make more targeted preventions.

Researching on distribution of coal mine rescue accident's location can be done from two aspects. First, the physical environment of coal mine operations, which is natural partition in coal mine when exploiting. Second, functional units in coal mining operation, which are disaggregated units with similar functions. Since the coal mine itself complex operating environment, this paper will consider both physical and functional units when thinking about locations. Locations in statistical samples are listed in the following table 2:

Table 2: Distribution of coal mine rescue accidents' locations

Location	Number	Location	Number
mining return air stone door	14	main haulage roadway	4
coal face	12	auxiliary shaft	2
gob	8	hoist house	2
transit haulage way	6	main shaft	2
contact lane	6	mountain track	1
fire dam	5	open-off cut	1
driving lane	6		

Through the above statistical analysis, locations ofcoal mine rescue accident sample library established in this paper have 13 places: mining return air stone door, coal face, gob, transit haulageway, contact lane, fire dam, driving lane, main haulage roadway, auxiliary shaft, hoist house, main shaft, mountain track, open-off cut. Among

them, coal mine rescue accidents happen most in mining return air stone door with the number of 14 (20.29%). Following is coal face, 12 cases accounting for 17.39%. The third is gob, 8 accidents accounting for 11.59%.

There are two locations which has more than 10coal mine rescue accidents: mining return air stone door and coal face. Gob, transit haulageway, contact lane, fire dam and driving lane are the five locations who have 5-9 accidents. Total accidents happened in above 7 locations are 57, which takes 82.61% of all samples. Therefore, during the analysis, these locations should be focused to accurately grasp the key points of the general rules about coal mine rescue accidents' occurrence. What's more, influencing factors and risk's degree should be specifically analyzed in these locations. These actions can pointedly prevent accidents occur in this site and overall reduce the accident rate, to ensure coal mine rescue work will be effectively carried out.

3.3 Type Distribution

Types of coal mine rescue accidents are environmental conditions in this paper. Many types of coal mine accidents may occur in the mining processdue to their differences in conditions, such as gas explosion, fire, flooding, coal and gas outburst, etc. Different types of accidents usually have different conditions and different means, as well as the risk faced by rescue team and the severity of the accident. Preliminary statistics can show, as the different types of accidents, there is a big difference in the extent of casualties in mine rescue team members. Therefore, discussing the proportion of coal mine rescue accidents in different types of accidents have multiple advantages. On the one hand, it contributes to have a more detailed classification of samples. Onthe other hand, preliminary understanding about objective environment can be made and propose targeted prevention measures. Those will effectively reduce the occurrence of coal mine rescue accidents.
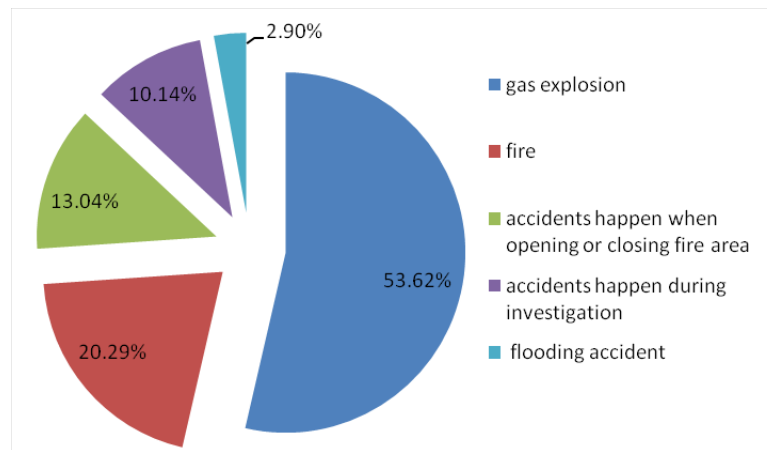
Figure 3: Proportions of different types' accidents

From the analysis of figure 3, in all statistical accidents: most coal mine rescue accidents happen in gas explosion, with 37 cases (53.62%); No.2 is fire, 14 cases (20.29%); No.3 is accidents happen when opening or closing fire area, 9 cases (13.04%); No.4 is accidents happen during investigation, 7 cases (10.14%); last is flooding accident, with 2 cases (2.90%). Just from this perspective, the focus of preventing coal mine rescue accidents is to prevent gas explosion, fire and opening (closing) fire zone (total proportion up to 86.96 %). Focus on improving the rescue safety of these three accidents will effectively reduce the accident's occurrence and casualties.

To analyze the specific situation of casualties in various types of accidents, specific reasons for each type are as follows:

Table 3: Numbers of different types' accidents

Type	Specific Reason	Number
	poisoning	8
Fire Accident	explosion	3
	heat	3
	toxic suffocation	13
Gas Explosion	blast	20
	other secondary injuries	4
Opening (Closing) Fire Zone	toxic suffocation	8

	explosion	1
Flooding Accident		2
Investigation Accident	toxic suffocation	6
	falling	1

As the table 3 shows, in fire accidents, the main factors are poisoning (8 cases), explosion caused by fire (3 cases) and heat (3 cases). In gas explosion, the main factors are toxic suffocation (13 cases), explosion blast (20 cases) and other secondary impact injuries (4 cases). In opening or closing fire zone, the main factors are toxic suffocation (8 cases) and explosion (1 case). In investigation, the main factors are toxic suffocation (6 cases) and falling (1 case). Blast injury in gas explosion happened most, 20 times; followed by toxic suffocation in gas explosion, 13 times.

On specific division of injury factors,forms can be divided into toxic suffocation, explosion blast, heat injury, drowning flood, secondary injury of gas explosion, falling. Specific accounting case as shown below.
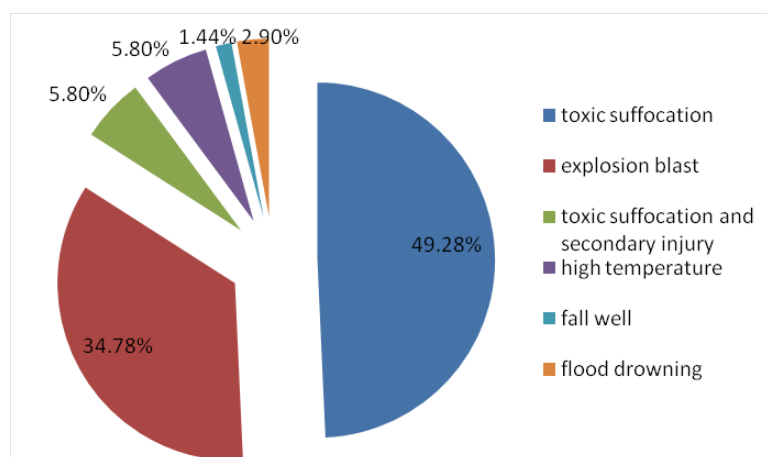

Figure 4: Numbers of different injury factors

By the statistics in figure 4, we can know the factor causing most injuries is toxic suffocation (34 cases, 49.28%); second is explosion blast (24 cases, 34.78%); third are toxic suffocation and secondary injury, both are 5.8%. Through analysis,the major factors of coal mine rescue accidents are toxic suffocation and explosion blast, with a total of 84.06%.Similarly, when the mine rescue team rescuing, these two factors need to considered most to reduce casualties.

3.4 Ownership Distribution

The nature of the ownership of enterprises is an important factor affecting the incidence of coal mine rescue accidents, rescue capabilities, and rescue effectiveness. The classification and analysis of the samples of coal mine rescue accidents according to the nature of the enterprise's ownership is an important aspect of in-depth exploration of the causes of coal mine rescue accidents. According to the ownership nature of coal mining companies, the coal mines in the sample library are divided into three categories: state-owned key coal mines, state-owned local coal mines, and township coal mines. By analyzing the relationship between the occurrence of coal mine rescue accidents and the ownership of coal mining enterprises, it is possible to formulate appropriate prevention and control measures, which is more conducive to reducing the occurrence of coal mine rescue accidents.

Table 4: Ownership of enterprises in coal mine accidents

enterprise's ownership	Accident amount	Proportion
state-owned key coal mine	29	42.03%
state-owned local coal mine	30	43.48%
township coal mines	10	14.49%

From the above table, it can be seen that the largest proportion of the country's total is the state-owned local coal mines, followed by the state-owned key coal mines, and finally the township coal mines. Township coal mines account for a relatively small proportion of coal mine rescue accidents. This is due to the fact that the township coal mines usually have a relatively small scale of mining. The accidents that occur are generally not very large and the underground mining structure is relatively simple. In this way, when there is a coal mine accident, it is more conducive to the development of coal mine rescue activities. What's more, the township coal mines usually have weak rescue capabilities. If a major coal mine accident occurs, usually a higher-level mine rescue team will be mobilized to participate in the rescue. Higher-level mine rescue teams will be able to handle the rescue accidents in township coal mines.

The mine rescue forces of the state-owned local coal mines are generally weaker than those of state-owned key coal mines, and there is also a certain gap between the degree of specialization and the equipment allocation of mine rescue teams. However, this difference is limited. Therefore, the proportion of state-owned key coal mines and state-owned local coal mines is similar, at 42.03% and 43.48%, respectively.

On the whole, among all the enterprises that have been involved in coal mine rescue accidents, state-owned coal mines (including state-owned local coal mines and state-owned key coal mines) accounted for 85.51% of the total, while the township coal mines only accounted for 14.49%.

This is usually not due to the incomplete mine rescue system of the state-owned coal mines and the low professional skills of the mine rescue team. But because of the large scale of state-owned coal mines, the mining environment is also relatively complex. Once a coal mine accident occurs, the scale of the accident will be large. From the sample database, it can be seen that coal mine accidents in state-owned coal mines are usually major accidents and extreme major accidents. The objective environment has created a serious problem in mine rescue operations. Therefore, the proportion of rescue accidents in coal mines is relatively large.

Among the coal mines where rescue accidents occurred, there are 61 coal mines legally mined (88.41%), 8 coal mines illegally mined (11.59%). It can thus be seen that illegal mining still occupies a considerable. The legitimacy of mine operations will affect the occurrence of coal mine rescue accidents to a certain extent.

Table 5: The proportion of legal and illegal coal mines in different forms of ownership

ownership	Operational legality	amount	proportion
state-owned	Legal mining	48	97.96%
	Illegal mining	1	2.04%
township	Legal mining	13	65%
	Illegal mining	7	35%

From the above table, it can be seen that there is a huge difference between the amount of legally illegally exploited coal mine units in different forms of ownership and

their respective proportions. It can thus be seen that in the state-owned coal mines, the occurrence of coal mine rescue accidents is not closely related to the legitimacy of the coal mining enterprise. Or it can be said that in state-owned coal mines where coal mine rescue accidents occur, the proportion of illegal mining accounts for only a small percentage. In the township coal mines, the occurrence of coal mine rescue accidents is associated with the legitimacy of the coal mine unit mining, including illegal coal mining up to 35%. This means that illegal exploitation in township coal mines is an important cause of accidents. In the prevention of coal mine rescue accidents, we must pay attention to the legal exploitation of township coal mines.

3.5 Chapter Summary

Following conclusions have been drawn:

(1) Definition of coal mine rescue accident have been given. Coal mine rescue accident is the incident which occurs in the process of coal mine rescue crew disposing disaster or accident, and it will result in further expansion of the accident. The consequences include casualties of rescue workers and other people, as well as further destructiveness.

(2) Established the sample library of 69 accidents (1981-2011), which is major, serious or destroyed. Principles of selection are comprehensive description, severity, recent time.

(3) Analyze the sample library of coal mine rescue accidents from the four aspects of the distribution pattern of the death toll, location, type, and the ownership forms.

(4) In 69 coal mine rescue accidents, casualties of rescuers are mostly from 3 to 10 accidents in this phase are up to 62.32%.

(5) Coal mine rescue accidents mostly happen in following seven locations: mining return air stone door, coal face, gob, transit haulageway, contact lane, fire dam, driving lane. 57 accidents occurred in these locations, occupying a total of 82.61%. These seven locations are key areas of preventing and controlling coal mine rescue accidents.

(6) In all statistical mine rescue accidents, most occur in the rescue progress of gas explosion accident. Followings are fire accident, opening (closing) fire zone, investigation, flooding accident.

(7) Rescue team have 86.96% accidents when they rescue in gas explosion, fire and opening or closing fire zone. The first two factors of injury level are toxic suffocation and gas explosion blast, which the sum up to 84.06%.

(8) Considering the ownership of enterprises who happened coal mine accidents, state-owned coal mines (including state-owned local coal mines and state-owned key coal mines) accounted for 85.51% of the total, while the township coal mines only accounted for 14.49%.

4   Analysis of Unsafe Acts in Coal Mine Rescue Accidents

This paper analyzes unsafe acts in coal mine accidents caused by rescue. In the analysis process of unsafe acts, direct unsafe acts, which result these accidents, are stripped out firstly. The categories of direct unsafe acts and the specific acts are the focus of analysis. When analyzing related unsafe acts, all unsafe acts are divided and analyzed according to the different mechanisms, finding out the high-frequency unsafe acts to provide evidence for the prevention of coal mine rescue accidents.

4.1   Explanation of Unsafe Acts' Concept

To clear the acts reasons of coal mine accidents caused by rescue, three concepts in this article relates to unsafe acts, namely: direct unsafe acts, related unsafe acts and high-frequency unsafe acts. Their relationship is as shown in Figure 5 (Wei J., Zhi-ming Z., Yuan-chi X,2016).
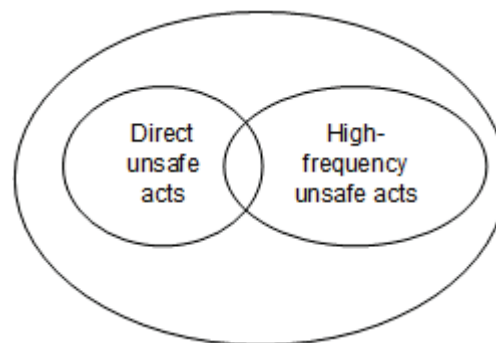

Figure 5: Relationship among direct, related and high-frequency unsafe acts

Direct unsafe act of coal mine accidents caused by rescue is the act which cause the accident, a distinctive feature of this act is it directly cause the accident.

Related acts include both direct unsafe acts which directly cause mine rescue accident, but also incentive acts, or the unsafe acts which may influence the following evolution of the accident.

High-frequency unsafe acts are high-frequency ones in statistics of related unsafe acts. Although these acts don't directly cause the accident, but they do have important influence on accident' s happening and development.

Therefore, this paper focuses on the direct unsafe acts and high-frequency unsafe acts of coal mine accidents caused by rescue.

4.2 Preliminary Statistics of Unsafe Acts

This paper selects 69 mine rescue accidents from 1981 to 2011, whose level are major, serious or destroyed (general accidents are not considered) in china.These accidents widely cover different occurrence types of mine rescue accidents, such as gas explosions, flooding, fire, etc. They also widely include state-owned key coal mines, state-owned local coal mines and township coal mines. Besides, the development of coal mine rescue technology in this period is relatively stable.

4.2.1 Statistics of Direct Unsafe Acts

By analyzing acts in 69 coal mine rescue accidents in the sample library, the statistical results of direct acts are in Table 6 below:

Table 6: Statistical table of unsafe acts in coal mine rescue accident

No.	Type	Specific Form	Number of Times	Proportion
1	Not wearing respirators as required	not wearing respirators when rescuing	11	15.94%
		talking through respirator in the underground rescue	8	11.59%
		removing the respirator without authorization	7	10.14%
2	Not following the requirement of gas detection	not detecting gas in rescue space before working	9	13.04%
		not detecting underground gas components dynamically as required	5	7.25%
3	Rescue crew's poor ability	unable to carry out self and mutual aid in emergency	4	5.80%
		not carrying rescue equipment like resuscitator	6	8.70%
4	Technical measures are not in place	taking wrong coal mine rescue measures when the underground situation is unclear	5	7.25%

5	Violation commanding	forcing rescuers break into the pit with unknown details	6	8.70%
		forcing rescuers work with the awareness of bad rescue condition	4	5.80%

Among the specific direct unsafe acts, there are 6 factors in the front rank: not wearing respirators as required (15.94%), not detecting gas in rescue space before working (13.04%), talking through respirator (11.59%), removing the respirator without authorization (10.14%), not carrying rescue equipment like resuscitator (8.70%) and forcing rescuers break into the pit with unknown details (8.70%). The sum of six direct unsafe acts of coal mine rescue accidents takes 68.11% of all samples. So, these six factors are the point of controlling concrete behaviors to effectively prevent coal mine rescue accidents.

4.2.2 Analysis of Direct Unsafe Acts

Table 1 shows that the direct unsafe acts of mine rescue accidents have five categories: not wearing respirators as required, not following the requirement of gas detection, the rescue crew poor ability, technical measures not in place and violation commanding. These categories are shown in table 1. The percentage data in Table 1 is the percentage of direct unsafe actions in the sample, which accounts for the frequency of the direct unsafe actions.

(1) Not wearing respirators as required. Respirator is one of the most important protective tools for rescue crew when conducting underground mine rescue. It can not only guarantee the rescuers' work when rescuing trapped people, but also be the important barrier for rescuers themselves. It can be found by analysis that not wear respirators as required have three specific forms: not wearing respirators when rescuing (15.94%), talking through respirator in the underground rescue (11.59%), removing the respirator without authorization(10.14%).

(2) Not following the requirement of gas detection. Usually when an accident occurs in the mine, it will affect the normal operation of the ventilation system, or local underground harmful gases and gas exceeding because of gas explosion or fire. If rescuers work underground without previous detection, it may a second explosion or other injuries which can lead to further accidents. There are two main concrete

manifestations by statistics: not detecting gas in rescue space before working (13.04%), not detecting underground gas components dynamically as required (7.25%).

(3) Rescue crew's poor ability. It has multiple forms, embodied in the lack of mine rescue common sense, can't start rescue work expertly, not skilled in using rescue equipment, significant errors due to nervousness of emergency, etc. Since rescuer is one of the most important participants in mine rescue, their ability direct influence the smooth and orderly conduct. There are two main concrete manifestations by statistics: unable to carry out self and mutual aid in emergency because they don't know how to use rescue equipment, not carrying rescue equipment like resuscitator. Among these accidents, there are 4 accidents (5.8%) happened because they can't carry out self and mutual aid in emergency and 6 accidents (8.7%) happened because they don't carry rescue equipment like resuscitator.

(4) Technical measures are not in place. Technical measures in mine rescue will directly affect the effect of rescue. Rescue of coal mine accidents is relatively complex and the risk is relatively high. Specific circumstances of different accidents types and different environmental factors often lead to different levels of complexity. Then making practical technical measures is vital. There are two main concrete manifestations by statistics: taking wrong coal mine rescue measures when the underground situation is unclear, not making safety rescue and protection measures by rule. The former led to 5 accidents, which taking 7.25% of the total samples.

(5) Violation commanding. It is for the commanders in coal mine rescue. After the accident, disaster relief command system must be set up immediately to take charge of the site guidance and scheduling according to "mine rescue procedures". Command system is the instruction sponsor of a mine rescue team, whose decision and command have direct impact on mine rescue team's action. Violation commanding can lead to the occurrence of coal mine rescue accident, or cause disorder and affect mine rescue process. There are two main concrete manifestations by statistics: forcing rescuers break into the pit with unknown details, forcing rescuers work with the awareness of bad rescue condition. Among them, the former caused 6 accidents (8.7%) and the latter caused 4 accidents (5.8%).

4.2.3 Proportion of Direct Unsafe Acts

Figure 6 shows that there is a big difference in the proportion between 5 unsafe acts of coal mine rescue accidents. Not wearing respirators as required accounts for the largest proportion for 37.68%, and not following the requirement of gas detection is No.2 which accounts for 20.29%. Rescue crew poor ability and technical measures not in place accounts for third as 14.49%. The last one is violation commanding whose proportion is 13.04%. The first two has a larger proportion, as the sum of them is 57.97%, more than half. Therefore, in the five categories of direct unsafe acts, the focuses of prevention and control are not wearing respirators as required and not following the requirement of gas detection. It can greatly reduce the occurrence rate of mine rescue accidents if control these two factors well.
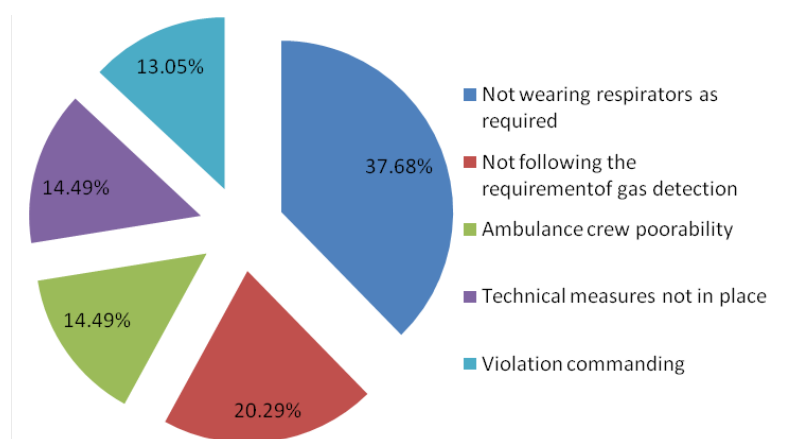

Figure 6: Proportion of different direct unsafe acts (in percentages)

4.3 Statistical Classification of Related Unsafe Acts

Statistics of unsafe acts in this section are one-time acts in every coal mine rescue accident, which means all once unsafe acts relevant to the accident. All direct unsafe acts and relevant unsafe acts which led to accident are contained.

4.3.1 Statistical Types of Unsafe Acts

In order to facilitate the analysis of coal mine rescue accidents, we need to do some induction and consolidation. On the basis of reading abundant coal mine accident cases, using the statistical methods in last section, related unsafe acts of coal mine rescue accidents are divided into 11 categories: not wearing respirators as required, not carrying necessary technical equipment, not detecting gas as required, poor ability of rescuers, technical measures not in place, pro-examination not in place, violation

commanding, daily management of rescue team not in place, rescuers' violation acts, poor emergency capability, commanding error. These unsafe acts can be subdivided into 72 categories, which cannot be enumerated due to limited space.
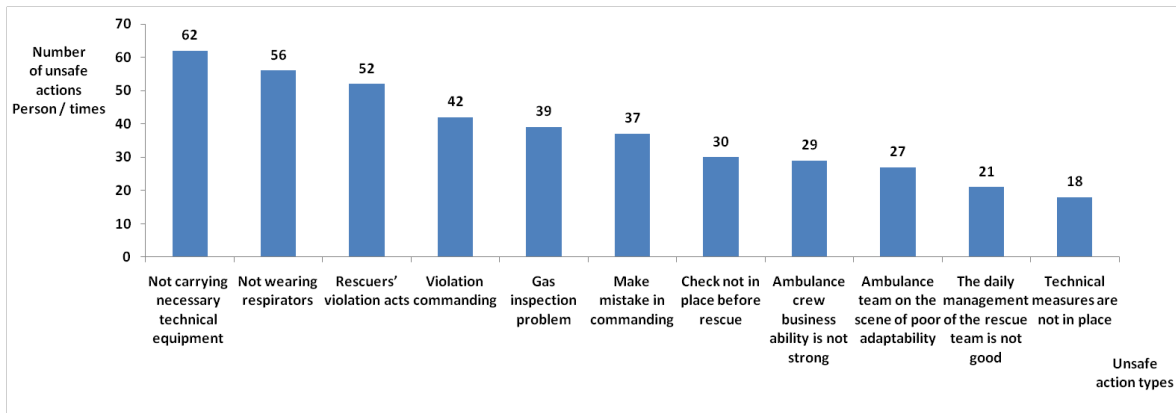

Figure 7: Distribution of different types of unsafe acts

Figure 7 shows there is a frequency distribution among these types: (1) not carrying necessary technical equipment appears most with 62 people / time (14.87%), (2) not wearing respirators as required with 56 people / time (13.42%), (3) rescuers' violation acts with 52 people / time (12.47%), (4) violation commanding with 42 people / time (10.07%). These four types of unsafe acts are the highest-frequency ones with the sum of 50.83%, others appear relatively less.

4.3.2 Classification Analysis

This section will provide a detailed analysis of the unsafe acts of each type of coal mine rescue accident, analyze the specific unsafe acts of each type of unsafe behavior, and provide a more accurate direction for the prevention and control of unsafe acts.

(1) There are four kinds of specific unsafe act manifestations for the failure to wear respirator as required. They are not wearing respirator when performing rescue operations, talking by mouth breathing when downhole rescuing, removing the respirator without authorization and taking off at the mouth appliance when rest in disaster area. Among them, the frequency of the first occurrence was the highest, 18 people per time, accounting for 4.32%; then is 17 people per time, accounting for 4.08%; then is 12 people per time, accounting for 2.88%; then is 9 people per time, accounting for 2.16%.

(2) There are seven kinds of specific unsafe act manifestations that are not carry necessary technical equipment. They are: no lighting equipment, no two-hour

respirator, no lifeline, not bringing disaster-phone, no replacement oxygen bottle wrenches, not carrying emergency equipment, and not carrying spare respirator. Among them, the frequency of not carrying spare respirator are the highest, with 14 persons per time; followed by 13 people/times without telephones in disaster-affected area; and not carrying lighting equipment ranked at the third place with 11 persons/time. The other four kinds of specific unsafe actions occur relatively less frequently.

(3) There are four main types of unsafe act manifestations in gas detection. Among them, the highest frequency is not detecting gas components as required, which is 16 persons per time; the gas that did not detect before entering to rescue is frequency of 11 persons per time; the third is not setting a special person to test the gas at the closed side of the air inlet side, with 8 people/time; unsafe act before the unsealed fire area is found to be relatively low, with 4 people/time.

(4) There are eight kinds of specific unsafe act manifestations for the rescue crew's operational ability. Among them, no provision for returning time to the disaster area for reconnaissance is the most unsafe act occur, 7 people/time; followed by can't use emergency equipment to do self-rescue and mutual rescue in emergencies, the frequency of 5 people / time; the third is the traffic lane fork without safety signs and warning signs, and no signing when walking in the roadway, both 4 persons/time; the frequencies of other three unsafe acts are relatively small.

(5) There are three types of specific unsafe act manifestations in place of rescue measures. Among them, the highest frequency of unsafe acts is not checking one by one according to the fire zone unsealing plan, 8 people/time; followed by not strictly implement the prescribed rescue measures according to regulations 6 people/ time, the use of erroneous coal mine rescue measures occurred at the lowest frequency of 4 people/time.

(6) There are three kinds of specific unsafe movements in pre-war inspections. Among them, no pre-inspection of the equipment is the highest frequency of unsafe acts, 14 people/time; followed by no pre-inspection and inquiry of the rescuers' physical condition, 9 people/time; the last is no timely replacement of carbon dioxide absorbent, 7 people/time.

(7) There are ten specific types of unsafe act manifestations in violation of command. Among them, forcing rescuers break into the pit with unknown details is the highest

frequency of unsafe act, 11 people/time; the second is to force the rescue team to rescue when all downhole people are determined to be dead 8 people/time; the third is keep requiring rescue operations in case of overdrafts, 5 people/times; the fourth is illegally forcing reproduction under the outbreak of fire, 4 persons/time; the frequency of the remaining six unsafe actions are low.

(8) The daily management of the rescue team includes six specific unsafe acts. Among them, not washing used respirator occurs the highest frequency of 7 people / time; then, no regular business training for rescue crew is 6 people / time; thirdly, the rescue equipment is not inspected every two weeks in accordance with the regulations, 5 people/time; the fourth is not establishing an instrument maintenance system 4 people/ time; The other two types of unsafe acts occur less frequently.

(9) The rescue crew's illegal acts mainly include 11 kinds. Among them, the highest frequency of unsafe acts is less than six people going down, 13 people/time; then could not see the distress signal when team members separate operate, 8 people/times; the third is the violation of "a respirator should rest for at least 8 hours after class", 6 persons/time; frequency of other 8 types of unsafe acts are relatively low.

(10) The rescue team's on-site emergency response capabilities include six specific unsafe acts. Among them, lack of on-site emergency response capacity, shouting after mouth appliance off is the highest frequency of unsafe acts occurring 10 persons/time; then not take proper measures to cause poisoning to accelerate, 7 people/times; the third is the confusion causing team members to roll and fall into a well, 4 people per time; the frequency of other three kinds of unsafe acts are relatively low.

(11) Command errors mainly include ten specific unsafe acts. Among them, the unsafe act with the highest frequency of occurrence was that the multi-headed rescue command department had not been set up in a timely manner. The frequency of such unsafe acts was 9 people/time; the second was the failure to evacuate the ambulance personnel in the event of an unknown fire. To the safe area and the rescue team did not have a standby team, the frequency of these two types of unsafe acts was 5 persons/time; the frequency of occurrence of the third was the miscalculation of downhole conditions, and the frequency of such unsafe acts was 4 persons/times. .

4.3.3 High-frequency Unsafe Acts

This section calculates out 19 categories of high frequency unsafe acts on the base of 72 relevant unsafe acts in last section, making it more targeted on controlling and preventing coal mine rescue accidents.

Table 7: High-frequency unsafe acts causing coal mine rescue accident

No.	Specific Form	No. of Times
1	Not wearing respirators when rescuing	18
2	Talking by mouth breathing when downhole rescuing	17
3	Not detecting underground gas components dynamically as required	16
4	not carrying spare respirator	14
5	no pro-examination of equipment	14
6	not bringing disaster-phone	13
7	go down to rescue with less than six people	13
8	removing the respirator without authorization	12
9	Not carrying lighting equipment	11
10	not detecting gas in rescue space before working	11
11	forcing rescuers break into the pit with unknown details	11
12	Lack of on-site emergency response capacity, shouting after mouth appliance off	10
13	Taking off at the mouth appliance when rest in disaster area	9
14	no inspection and inquiry about physical condition of the rescue crew before working	9
15	Not timely establishment of the repair headquarters, multiple and confused command	9
16	Not let someone check gas in the closed downwind side	8

17	No checking one by one according to the fire zone unsealed plan	8
18	forcing rescuers work with the awareness of bad rescue condition	8
19	Working alone, not able to see the distress signal	8

Statistics of high frequency unsafe acts can show which has higher frequency in unsafe acts related to accidents. It provides some evidence for later safety training, as well as prevention and control of rescue accidents.

According to the above statistics, top 5 specific high- frequency unsafe acts are: not wearing respirators when rescuing, talking through respirator in the underground rescue process, not dynamic testing underground gas composition, not carrying spare respirator, no pro-examination of equipment. The 19 key statistics high-frequency unsafe acts are the point of controlling and preventing coal mine rescue accidents, and the 5 high-frequency unsafe acts are the priority among priorities in table 2.

4.4 Chapter Summary

Following conclusions have been drawn:

(1) In order to make the acts reasons lead to coal mine rescue accidents clearer, we classified the concepts of unsafe acts, namely: direct unsafe acts, relevant unsafe acts and high-frequency unsafe acts.

(2) There are five categories of direct unsafe acts which cause coal mine rescue accidents：not wearing respirators as required, not following the requirement of gas detection, the rescue crew poor ability, technical measures not in place and violation commanding.

(3) There is a big difference in the proportion between 5 direct unsafe acts of coal mine rescue accidents. Not wearing respirators as required accounts for the largest proportion, and the second is not following the requirement of gas detection. Rescue crew poor ability and technical measures not in place tie for third, and the last one is violation commanding. The first two has a larger proportion, as the sum of them is 57.97%, more than half.

(4) Nineteen categoriesof high-frequency unsafe acts are statistic out of all relevant unsafe acts, and 5 types are well-marked due to the higher frequency: not wearing

respirators when rescuing, talking through respirator in the underground rescue process, not dynamic testing underground gas composition, not carrying spare respirator, no pro-examination of equipment.

5 Precautions of Coal Mine Rescue Accidents

After analysis of causes of unsafe acts in coal mine rescue accidents, serval related precautions have been put forward for rescue teams or mine organizations to control the occurrence of this type of accidents.

5.1 Wear Breathing Apparatus as Required

Respirator is a kind of personal protective equipment worn by rescue members in hazardous gas environment. It can not only guarantee to carry out rescue work smoothly and rescue the trapped people, but also is an important barrier for rescue team members to protect themselves.

According to the "Coal Mine Safety Regulations" (National Administration of Safety, 2011), following precautions should be implemented:

(1) When the mine rescue teams dispatch rescue missions, they must wear mine rescue protective clothing, wear and use oxygen breathing apparatus as required, and carry relevant equipment, instruments and supplies.

(2) All members must check the oxygen breathing apparatus before entering disaster area. The oxygen pressure of the oxygen breathing apparatus must not be lower than 18 MPa, and not be lower than 5 MPa during the use.

(3) When it is found that the combatants are unwell or the malfunction of the oxygen breathing apparatus is difficult to remove, the entire team must withdraw immediately.

(4) Rescuers should rest at least 8 hours after working in a respirator class in the disaster area.

5.2 Testing Gas Composition as Required

In the coal mine rescue work, the rescue team should often deal with the disaster accident, and the accident place is often the gas concentration abnormal area. The rescue team should be engaged in the rescue work in the environment of low oxygen, high gas and high carbon monoxide. Therefore, the correct use of gas detection equipment is a strong defense to ensure the safety of rescue team members.

In addition, when gas explosions or fires cause underground hazardous gases and gas to exceed the standard, if the coal mine rescue personnel do not conduct gas

detection in advance, they may cause explosions or other forms of injury when they enter the underground rescue work, resulting in further expansion of the accident. Therefore, the significance of gas component detection is very important. The common gas detection instruments are interferometric methane detector, catalytic combustion methane detection alarm, CO detection alarms, and O_2 detection alarms.

5.3 Improving Rescuers Ability

Rescue team must improve their ability for coal mine rescue assignment.

(1) Strict education and training.

The new players should do a good job in basic training and team formation, and all the combatants should do a good job in education and training. The rescue team must learn the basic theories and basic skills of rescue and disaster relief, do a good job of "safety first" ideological education, enhance compliance with law, and improve the overall quality of the ambulance crew.

According to the Coal Mine Dispatch Regulations, the commanders and soldiers of mine rescue teams and auxiliary mine rescue teams must undergo basic training on compulsory rescue theory and techniques and skills. They must conduct strict military training. Exercise training must be combined with actual combat needs.

(2) Improving the management system.

Strengthening the daily management of mine rescue teams is the basis for coal mine rescue work. The mine ambulance team implements militarized management, and all members must receive military training. The mine rescue team must have strict organization, strict discipline, strict requirements, strict management at all times to ensure a high level of readiness for preparations, and to achieve a "calling, fighting, and winning" result.

The mine rescue team must do a good job in scientific management. The rescue team is the main force in handling coal mine accidents. The quality of its members plays an important role in the success of disaster relief. Its qualities include "safety first" thinking, obedience and compliance, awareness of disaster relief, rescue knowledge, disaster relief operations skills, independent safety capabilities, mutual safety capabilities, and physical quality.

5.4 Avoid Violation Commanding

After disaster accidents in mines, strengthening the organization and leadership of disaster relief and disaster prevention, and formulating correct disaster relief plans are the key to quickly and effectively handling accidents, and are also the key to avoiding casualties.

(1) Each mine must, in accordance with national safety production laws and regulations, formulate plans for the prevention and treatment of mine disasters, and make timely amendments and improvements when conditions change.

(2) Each mine must have a mine rescue team to serve it. Each rescue team should formulate treatment plans and safety technical measures based on the main types of disasters in mines and conduct planned drills. When a disaster occurs, the rescue team should immediately start the implementation of the pretreatment plan after receiving the order.

(3) After a major accident in a mine, a rescue commander headquarter must be established immediately by the mine chief to ensure the unified command, unified arrangement, and unified action of rescue and relief work.

(4) In order to prevent decision-making mistakes or violation commanding in the process of rescue, the cadres at all levels of coal mines must pass training, be familiar with the basic knowledge of mine rescue and command principles. They also need master the operational principles and safety technical measures for handling various types of coal mine accidents.

5.5 Improving Technical Measures

Relying on advances in science and technology, promoting the use of new rescue technology and equipment is an important way to complete the emergency rescue and disaster relief, to avoid the loss of rescuers themselves.

According to the current state of science and technology development, it is necessary to actively promote the use of positive pressure full-face oxygen breathing apparatus, portable explosive triangle detector, ice-cooled heat-resistant clothing, and communication equipment in disaster areas. At the same time, the organization should actively develop the research and development of mine rescue new

equipment, new instruments, and new technologies. People should create conditions to use computer technology for the development of mine rescue simulation training, daily management and disaster relief programs, and constantly improve the level of mine rescue technology.

6 Conclusions and Prospects

6.1 Main Research Conclusions

(1) The definition of the coal mine rescue accident and the sample selection principle of the coal mine rescue accident are proposed, and a sample library of coal mine rescue accidents is established through the formulated principles. The sample library has 69 accidents from 1981 to 2011, according to comprehensive description, severity, time principles.

(2) Separated analysis are done from following four aspects, which are the distributions of: death toll, location, type and enterprise's ownership. Casualties of rescuers are mostly from 3 to 10 accidents in this phase are up to 62.32%. Most of coal mine rescue accidents happen in mining return air stone door, coal face, gob, transit haulageway, contact lane, fire dam, driving lane, with a total of 82.61%. Most accidents occur in the rescue progress of gas explosion accident. 85.51% accidents happened in state-owned coal.

(3) Related unsafe acts of coal mine rescue accidents are divided into 11 categories, with 72 kinds of unsafe acts. Not carrying necessary technical equipment appears most with 62 people / time (15.94%), not wearing respirators as required with 56 people / time (11.59%), rescuers' violation acts with 52 people / time (12.47%), violation commanding with 42 people / time (10.07%). These four types of unsafe acts are the highest-frequency ones with the sum of 50.07%, others appear relatively less.

(4) On the basis of statistics and analysis of all unsafe acts, 19 types of high-frequency unsafe acts that lead to are statistically recorded, making the prevention and control of coal mine rescue accidents more targeted. Among them, not wearing respirators when rescuing, talking through respirator in the underground rescue process, not dynamic testing underground gas composition, not carrying spare respirator, no pro-examination of equipment are the top 5.

6.2 Prospects

In the follow-up work, improvement of this thesis's deficiencies need to be continued, mainly in the following aspects:

(1) Further establishment of a sample library for coal mine rescue accidents, to include accidents with a number of casualties of less than 3 persons to make the sample analysis more accurate.

(2) Exploring the relationship between unsafe acts and related personnel levels in the accidents in coal mines.

(3) Explore the reasons for the level of organizational behavior in mine rescue accidents.

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8   List of Figures

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Thesis Grade

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Author: <u>Yuanchi XIANG</u>

Supervisor	<u>Fu Gui</u>	Grade	90	signature
Co-supervisor	<u>Nikolaus Sifferlinger</u>	Grade		signature