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Analysis of unsafe condition in coal mine accidents caused by rescue

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Abstract. he study of unsafe conditions and the relationship of the unsafe action and unsafe conditions is very important on the prevention of coal mine accidents caused by rescue. This paper selects the 69 coal mine rescue accidentsfrom 1981 to 2011. Focusing on analysis ofunsafe conditions resulted in accidents, and gets the following conclusions.Among the four unsafe conditions of coal mine rescue accidents, personal protective equipment's unsafe conditions have the highest frequency; followed in descending are unsafe conditions of other equipment, inspection and detection equipment, communications equipment.Unsafe conditions appear in personal protective equipment frequently are in insufficient oxygen supplement of oxygen breathing apparatus (6),nose clip lack of flexibility and falling off (8), oxygen breathing carbon dioxide absorber failure (7). Unsafe conditions appear in inspection and detection equipment frequently are carbon monoxide calibrating apparatus alarm fault (5), gas calibrating apparatus no alarm (4). Unsafe condition appears frequently in communications equipment frequently is poor calling effect (4). Unsafe conditions appear in other equipment frequently are insufficient oxygen supplement of oxygen cylinder (6) and air leakage of oxygen cylinder high-pressure gas pipe (4).It preliminarily explores the relevance of unsafe and unsafe conditions in coal mine rescue accident, and the reasons of unsafe conditions' occurrences.

Key words. Coal mine,accidents caused by rescue, unsafe condition, samples, analysis.

1. Introduction

Summarizing the lessons of coal mine rescue accidents andin-depth analyzing the reasons can help people take effective measures. It is an important means to c reduce coal mine rescue accidents and realize safe rescue.

Domestic scholars' studies in mine rescue always involve rescue system[1–4] and rescue technology[5–8], but rarely researches take accident entry point. Some domes-

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tic scholars research on the reasons of coal mine rescue accidents from the accidents themselves[9], and have got some results. These reasons contain poor mine rescue system, old mine rescue equipment, rescuers' poor technical quality and so on, but this aspect still need to be studied.

Therefore, this paper analyzes equipment commonly used in coal mine rescue, and uses the established device classification method to gather statistics based on the samples. Then we analyzed the specific manifestations of unsafe conditions of different accidents, and the relationship between unsafe acts and conditions. It is a new view to further analysis the reasons of coal mine rescue accide

2. Analysis of coal mine rescue equipment

This paper selects 69 mine rescue accidents from 1981 to 2011, whose level 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.

In a coal mine accident rescue, rescuers need strong equipment to ensure the efficiency and effectiveness of aid. Mine rescue process itself is complex, using many kinds of equipment (as Table 1).

Table 1. Coal mine rescue equipment

NO.	Equipment	Categories	Explanations
1	Communication Equipment	Phone In Disaster Area	Rescue timely feedback and ensure information communication between rescue organizations and staff
		Lead Line	Mine rescue team underground exploration rescue operation, mutual contact between the ambulance crew, confirm position in advancing the process of rescuers, guide the direction for subsequent rescue personnel and telephone lines
		Interphone	Close liaison between mine rescue personnel, is a portable communication tool
2	Personal Protective Equipment	Oxygen Breathing Apparatus	Usually wear 2h oxygen breathing apparatus, equipped with 4h breathing apparatus
		Automatic Resuscitator	positive and negative pressure artificial respiration to the wounded
		Rescuer	An auxiliary breathing equipment, mainly compressed oxygen
		SOS Device	In the event of an emergency situation, players can call for help through SOS emergency call device
		Helmet	Head protection of mine rescue personnel from injury
3	Testing and Inspection Equipment	Oxygen Detector	An instrument of detecting oxygen content in the environment
		Gas Calibrator	An instrument of detecting gas content in the environment
		Carbon Monoxide Calibrator	An instrument of detecting carbon monoxide content in the environment
		Infrared Thermometer	An instrument of detecting temperature in the environment
4	Other Tools and Equipment	Oxygen Cylinder	Spare oxygen equipment, the oxygen bottle can be used for emergency when respirators fail or oxygen is insufficient.
		Lifeline	auxiliary apparatus to keep rescuers safe when climbing blind well
		Stricken Guiding Device	Made by the cold light tube or bright lights in order to specify travel and return line for rescuers, as well as indicate escape routes for the people left behind
		Miner's Lamp	Not only illumination device, but also signaling device
		First Aid Kit	Usually have tourniquet, plywood, alcohol, bandages and other first aid common tools and medicines

3. Accident statistics of unsafe conditions

3.1. Classification and statistics of unsafe conditions

Unsafe condition is a result of a variety of reasons, which may lead to a complex result if we analyze it from its reasons. The main basis of analysis is the types of equipment. Statistics of unsafe condition is beneficial to analysis the reasons why unsafe condition produced in a coal mine rescue accident, thus providing the evidence for prevention. Unsafe conditions of 69 accidents are shown in Table 2 below.

Table 2. Classification and statistics of unsafe conditions

No.	Type	Specific Forms	Number of Times
1	Personal Protective Equipment	Lack of oxygen in oxygen breathing apparatus	6
		Oxygen breathing apparatus pressure reducer does not work, oxygen used fast	3
		Oxygen breathing apparatus automatically fill valve cover is loose, not self-complementary	2
		Positive and negative pressure of oxygen breathing apparatus is not airtight, exhaust and supplement too soon	3
		Carbon dioxide absorbent failure of oxygen breathing apparatus	7
		Nose clips lack of flexibility, loss	8
		Isolated rescuer fault	2
		Low pressure of resuscitator	2
		Rescuer candle fail to generate oxygen	3
2	Testing and Inspection Equipment	Gas calibrator no alarm	4
		Inspiratory rubber ball of gas calibrator has inadequateelastic	2
		Carbon monoxide calibrator's alarm fault	5
		Carbon monoxide calibrator's sensor aging	3
		Infrared thermometer battery lead fuse	1
		Oxygen calibrator does not display data	2
3	Communications Equipment	Stricken phone call poor	4
		interphone calls off	2
		Interphone loses electricity fast	1
4	Other Tools and Equipment	Oxygen cylinder's pressure gauge damaged	3
		Oxygen cylinder lack of oxygen	6
		Oxygen cylinder high-pressure gas pipe run	4
		Lifeline fracture	3
		Lighting lamp failure does notilluminate	3
		Lack of life-saving drugs insidefirst-aid kit (not replenish after use)	2
		Stricken guiding device's fluorescent agent failure does not emit	1

Overall, PPE, gas and other essential basic rescue equipment have higher possibility, whose sum is 80%. If you control these three categories of unsafe conditions, you can effectively control the coal mine rescue accidents caused by equipment's unsafe conditions.

(1) Unsafe conditions of personal protective equipment have 9 specific forms. Taken together, oxygen breathing apparatus is the biggest problem which takes 6/9 of all. Most of these problems are relevant to the routine maintenance of the instrument."Mine rescue procedures" states: "The rescue team should have timely maintenance and repair of equipment to ensure that mine rescue equipment and instrument are always in good condition".However, it may not be strictly implemented, so that cause accidents occasionally.

(2) Detection instruments'unsafe conditions mainly reflect in the six kinds of specific physical state. Detection instruments which have failures are gas detection equipment like gas calibrator, carbon monoxide calibrator, oxygen calibrator, etc. Reasons could be that they are the basic equipment in mine rescue with high-frequency use, which lead to severe loss and serious aging.Combined with poor routine maintenance, these instruments have frequent failures. "Militarized Mine Rescue Team Management Approach" No.44 clearly states: " All squad and personal equipment (breathing apparatus, resuscitator, self-rescuer, gas calibration, etc.) must be cleaned and disinfected after use. All of them need complement of spare items and need to be tested to meet the technical requirements to keep it in good state." Such accidents caused by equipment failure is often easy to prevent, but it is easy to overlook. The best way is to do routine maintenance and pro-detection well to find out equipment failure and eliminate hidden hazards.

(3) Communications equipment's unsafe conditions mainly reflect in three kinds of specific physical state with low-occurrence. The failures always are simple and concentrate upon phones and interphone in disaster area which can be troubleshot by simple routine tests.

(4) Other basic rescue equipment's unsafe conditions mainly reflect in 7 kinds of specific physical state. First isthe amount of oxygen cylinder not enough. Usually spare oxygen cylinders have 2h and 4h two sizes, but insufficient oxygen will make rescuers miscalculate the amount of oxygen and then lead to asphyxiation and poisoning accidents. Second is the air leakage of oxygen cylinder high-pressure gas pipe (4people/time). This mainly results in insufficient oxygen because it accelerates oxygen consumption. The presences of other five categories are low, less than 3people/time.

"Mine rescue procedures" clearly states that oxygen cylindersmust be oxygenated after use and all parts' condition must be checked and maintained in time. In practice, however, basic spare devices like oxygen cylinders may just use in one case or just several times, which lead to a lack of sense routine care and maintenance. However, even with relatively low frequency, daily cumulative loss is too large to be neglected. This is an important reason to explain whylow-frequency basic spare devices failed.

3.2. Classification and statistics of high-frequency unsafe conditions

The statistics of higher frequency unsafe conditions in Table 2 obtained 8 kinds of high-frequency unsafe conditions that cause coal mine rescue accidents. Results shown in Table 3 make the prevention and control of unsafe conditions more targeted.

Table 3. Statistics of high-frequency unsafe conditions

No.	Specific Forms	Number of Times
1	Lack of oxygen in oxygen breathing apparatus	6
2	Oxygen breathing's carbon dioxide absorbent failure	7
3	Nose clips lack of flexibility, loss	8
4	Gas Calibrator no alarm	4
5	Carbon monoxide calibrator's alarm fault	5
6	Stricken phone call poor	4
7	Oxygen cylinder lack of oxygen	6
8	Oxygen cylinder high-pressure gas pipe run	4

Because theseunsafe conditions above have higher frequency, proper control and prevention of them make it effective that can end unsafe condition become an accident[10].

4. Analysis of unsafe conditions related to unsafe acts

Unsafe conditions often have a close relationship with unsafe acts in coal mine rescue accidents, which means unsafe conditions are largely due to unsafe acts. Their relevance is shown in Table 4 below. Exploring the relevance between them has certain reference value to figure out reasons of unsafe conditions and to control them.

Table 4. Relationship between unsafe conditions and unsafe acts

Types of Unsafe Conditions	Related Acts	Related People
Personal Protective Equipment	No before checks of equipment	Rescue team's captain
	No timely replacement of carbon dioxide absorbent	Rescue team's captain,equipment user
	Oxygen breathing apparatus is not cleaned timely after use	Equipment user
	Not in accordance with the provisions to inspect the rescue equipment daily	Rescue team's captain
	Not use protective equipment as required	Equipment user
	No unified supplement after using the end of oxygenation	Rescue team's captain
	not wearing respirators when rescuing	Equipment user
	Talking by mouth breathing when downhole rescuing	Equipment user
Testing and Inspection Equipment	No before checks of equipment	Rescue team's captain
	Not timely replacement of rescue equipment with hidden troubles	Rescue team's captain
	Not timely unqualified instrument scrapped	Rescue team's captain
Communications Equipment	No before checks of equipment	Rescue team's captain
	Not timely unqualified instrument scrapped	Rescue team's captain
Other Tools and Equipment	No before checks of equipment	Rescue team's captain
	Not use protective equipment as required	Equipment user
	After using the life-saving drugs doesn't replenish enough	Equipment user

It can be seen from table 4 that each type of unsafe conditions corresponds to a series of unsafe acts. Unsafe acts may lead to unsafe conditions directly or put hidden hazard to it indirectly, but both can trigger unsafe conditions. So that mine rescue equipment or environment hazardsfail or out of control in a certain situation, then evolve into an accident. There are 3 main categories of relevant people who influence the process: rescue team captain, rescue team members and commanding

officers.From the table we can know that we need to start with those people to control corresponding unsafe acts, and further effectively eliminate or reduce artificial unsafe conditions turn into coal mine rescue accidents.

5. Conclusion

Following conclusions have been drawn:

(1) Statistics of unsafe conditions are on the basis of relevant equipment: communications equipment, personal protective equipment, inspection and detection equipment, other equipment and natural gas existing in coal mine.

(2) Among the four unsafe conditions of coal mine rescue accidents, personal protective equipment's unsafe conditions have the highest frequency; followed in descending are unsafe conditions of other equipment, inspection and detection equipment, communications equipment.

(3) Unsafe conditions appear in personal protective equipment frequently are in insufficient oxygen supplement of oxygen breathing apparatus(6),nose clip lack of flexibility and falling off (8), oxygen breathing carbon dioxide absorber failure (7). Unsafe conditions appear in inspection and detection equipment frequently are carbon monoxide calibrating apparatus alarm fault (5), gas calibrating apparatus no alarm (4). Unsafe condition appears frequently in communications equipment frequently is poorcalling effect (4). Unsafe conditions appear in other equipment frequently are insufficient oxygen supplement of oxygen cylinder (6) and air leakage of oxygen cylinder high-pressure gas pipe (4).

(4) This paper preliminary explores the relevance of unsafe conditions and unsafe acts in coal mine rescue accidents , as well as the reasons of unsafe conditions emergence.

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