Research on Behavior Cause of Limited Space Accident Based on "2-4" Model

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Abstract In order to prevent accidental casualties in the course of limited space operation, the behavioral safety "2-4" model is used to study the behavioral causes of typical limited space operation accidents. First, the causes of one-time and habitual behavior are studied from the individual level, that is, unsafe action, physical state and safety knowledge, consciousness; then, the research of operational behavior and guiding behavior is studied from the organizational level. Finally, the prevention and control suggestions are put forward to reduce the occurrence of such accidents.

1 INTRODUCTION:

Restricted space refers to the closed or semi-closed state, the staff can enter or explore and carry out non-continuous, unconventional work, limited entrance and exit, relatively isolated from the outside world. With the expansion of the scope of activities, production and life of all poor ventilation, easy to cause toxic and harmful gas accumulation or hypoxia of equipment, facilities and places are regarded as restricted space^[1]. In the statistics of safety accidents in recent years, the number of accidents occurring in limited space and the number of deaths occupy a considerable proportion, and more than 90% of the large accidents in limited space have the problem of increasing the number of casualties caused by blind rescue. According to the work situation confirmed by the General Office of the Ministry of Emergency Management, only 9 large accidents with limited space occurred in the industry and trade industry in 2016 and 31 people died; 13 large accidents with limited space occurred in the industry and trade industry in 2017 and 49 people died, accounting for 44.8% and 45.4% of the total number of major accidents in the industry and trade industry respectively; 61 accidents with limited space occurred and 112 people died in 2018. There were 9 major accidents. Of the 9 major accidents in 2018, 7 involved blind rescue, resulting in more than 18 deaths. With the national security situation improving year by year, The number of accidents and deaths in limited space operations are still increasing year by year. Therefore, it is of great significance to study the behavior cause of the limited space operation accident and to formulate the corresponding preventive measures to effectively reduce the occurrence of the limited space operation accident and reduce the number of accident deaths. This paper will study 10 typical limited space

operation accidents based on behavioral safety "2-4" model. The 10 accidents selected are shown in Table 1.

Table 1. Deaths from limited space operations

Time	Location	Number of casualties
8 August, 2014	Cangzhou City, Hebei	3 Dead 3 wounded
14 January, 2015	Honghe City, Yunnan	4 dead 8 wounded
19 October, 2015	Zhenjiang, Jiangsu	3 deaths
12 June, 2016	Tianshui City, Gansu Province	3 Dead 1 wounded
3 April, 2017	Xiangtan City, Hunan	4 dead 1 wounded
11 May, 2017	Sanming City, Fujian	4 dead 1 wounded
23 January, 2018	Liupanshui City, Guizhou	9 Dead 2 wounded
12 May, 2018	Hengshui, Hebei	4 deaths
23 March, 2019	Dali, Yunnan	3 dead 5 wounded
22 July, 2019	Zhangjiakou, Hebei	5 dead 4 wounded

2 Analysis on the Behavior Cause of Accident Personnel

In the ten typical accidents selected in this paper, the main types of injury include poisoning or asphyxiation,

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drowning, fire, explosion, collapse, burning and so on. Because of the complex working conditions and influencing factors in restricted space, when the rescue process does not take reasonable protective measures in time, it is extremely easy to cause secondary injury^[2] and easily cause the accident casualties to expand.

2.1 Direct cause analysis

1、human insecurity

An unsafe behavior refers to the action that causes an accident or has an important relationship with the occurrence of an accident. Unsafe behavior is mainly reflected in the restricted space operators without training and without a license to take up posts, not familiar with the risk factors of the working environment blind work and so on^[3]. This paper will combine the behavior safety "2-4" model, will comprehensively analyze the unsafe behavior of all kinds of personnel at all levels. This analysis yielded 14 unsafe behaviors, classified into 9 categories, as shown in Table 2. The frequency of occurrence of each type of unsafe behavior can provide data basis for accident prevention.

Table 2. Analysis of common unsafe behaviors

Unsafe behaviour	Frequency	Percentage share	Number of operations	Number of acts by supervisors
Blind rescue	7	25%	7	0
Lack of personal protection	5	17.8%	5	0
Absence of Guardians	4	14.3%	0	4
Lack of operational knowledge	3	10.7%	3	0
Not familiar with operation risk factors	3	10.7%	3	0
Lack of identification of system risks prior to operation	2	7.1%	0	2
Operation error in operation	2	7.1%	2	0
Failure to apply for restricted space work permits	1	3.6%	0	1
Untrained and undocumented	1	3.6%	1	0

It can be seen from the table that the problem of blind rescue without reliable safety measures occurs at the highest frequency of 25%, and the resulting increase

in casualties is also the most serious. Therefore, reducing blind rescue, adopting personal protection and effective personnel supervision are particularly important to reduce the occurrence of accidents in limited space operations^[4].

2、Unsafe state of things

The unsafe state is mainly caused by habitual behavior and the wrong disposal of the unsafe state of the fact accompli. According to the contents of the report and using the behavior safety "2-4" model to analyze the unsafe physical state, it is concluded that there are 9 common unsafe physical states that lead to the accidents in limited space operations^[5], as shown in Table 3. The occurrence of most unsafe physical conditions is mainly the existence of toxic and harmful gases or the formation of harmful gases in the operating space, which is the cause of most accidents in limited space operation, which accounts for 41.7% of the accidents.

Table 3. Common unsafe state analysis

Unsafe state of things	Frequency	Percentage share
Formation of harmful gases during operation	5	41.7%
Effective gas replacement is not in place before operation	2	16.7%
Inadequate operational area protection equipment	2	16.7%
Missing operational space monitoring device	2	16.7%
Risk factors or energy not effectively isolated	1	8.3%

2.2 Indirect cause analysis

According to the "2-4" model, the indirect cause of accident is defined as human habitual behavior, which mainly includes the safety knowledge, consciousness and habit of the accident initiator. Through the analysis of these 10 accident cases, there are 5 reasons for the lack of safety knowledge, as shown in Table 4.

Table 4. Indirect cause analysis

Lack of knowledge	Frequency	Percentage share
Lack of operation procedures or poor implementation	4	30.8%
Unable to identify the dangerous and harmful factors in the operation	3	23.1%
Weak sense of safety, poor working habits	3	23.1%
Emergency management system is not perfect	2	15.4%
Other safety precautions	1	7.7%

Through analysis, it is concluded that the lack of safety knowledge is mainly due to the lack of safety management system and operation rules^[6], accounting for 30.8%, while the training before the operation is a mere formality, and the risk and harmful factors can not be effectively identified after the training.

2.3 Radical cause analysis

In the analysis of the limited space operation accident, the "2-4" model holds that the incomplete safety system is the fundamental cause of the accident. Analysis of these 10 accident cases can be obtained, the safety management system is not complete a total of 5 categories, see Table 5. There are three categories of analysis of the certainty and inadequacy of security management, as shown in table 6.

Table 5. Analysis of Safety System for Accidents in Limited Space Operations

Inadequate security system	Frequency	Percentage share
Lack of perfect system and operating procedures	8	34.8%
Lack of safety awareness	6	26.1%
Inadequate and protective equipment	4	17.4%
Lack of emergency drill assessment system	3	13%
Insufficient risk identification and self-protection	2	8.7%

Table 6. Missing analysis of incident management in limited space operations

Safety management factors	Frequency	Percentage share
Emergency response disposal	5	45.5%
Safety System for Operation Monitoring	4	36.4%
Qualified personnel training	2	18.2%

Through the analysis of these 10 accidents, it can be found that in the aspect of safety management system, the lack of safety management system, operation rules and the lack of enterprise safety consciousness account for the largest proportion, 34.8% and 26.1%, respectively. In these accidents with the lack of enterprise safety system and consciousness, they are all related to enterprise management, so to change the unsafe behavior of personnel and the unsafe state of things in the operation^[7], we should start with enterprise management, establish the safety thinking of enterprises and perfect the safety management system.

2.4 Root cause analysis

The "2-4" model argues that the cause of the accident is a lack of safety culture. The safety culture includes the safety spirit culture and the safety material culture.

According to the analysis of this 10 accident investigation reports, it is not enough to explore the deep causes of the lack of corporate culture. According to the list of safety culture elements, this paper lists the missing safety culture elements involved in these 10 accidents. See table 7.

Table 7. Analysis of the absence of a safety culture

	Missing elements of a security culture		
1	Security importance	6	Role of the management system
2	All accidents are prevented	7	Forming the security system
3	Safety input awareness	8	Facility satisfaction
4	The formation of safety values	9	Role of security organizations
5	Security training needs	10	Emergency response capacity

The lack of enterprise safety culture has a serious impact on safety management from the root, and the slackness of operators' thinking leads to the failure of enterprise management system to play its expected role, and a good enterprise safety culture plays a role in promoting the formation of a reasonable safety management system for enterprises^[8]. Enterprises pursue economic benefits and ignore the importance of security, and the continuous reduction of security input leads to the failure to form correct security values^[9]. Therefore, in the process of management, enterprises should pay more attention to the leading role of culture, improve the overall safety literacy of employees in order to reduce the probability of accidents from the root.

3 conclusions

According to the "2-4" model of behavior safety, from the analysis of the causes of one-off behavior and habitual behavior, it is concluded that blind rescue is the most unsafe behavior without taking reliable safety measures; the most unsafe thing is the existence of toxic and harmful gases in the working space; and at the level of organizational behavior, the lack of safety management system and operation rules or the weak implementation of the operation rules reflect the weak status of enterprise safety awareness; the lack of safety culture construction is the root cause of the accident.

Through analysis, the organizational safety management system plays a vital role, especially in improving organizational behavior and personal behavior. In the process of enterprise safety management, the establishment of a good corporate safety culture requires the active participation and joint participation of all personnel of the enterprise.

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