Application Study of BBS on Unsafe Behavior and Psychology of Coal Miners

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ABSTRACT

Coal mining has become one of the most dangerous industries in the industrial sector, whose safety problem must be solved urgently. This paper is about the application and research of Behavior-based Safety management method in the coal mining enterprises. Taking Wangzhuang coal mine as an example, the paper carries out a comparative study of the unsafe behavior and psychology of coal miners before and after the implementation of BBS. In terms of the unsafe behavior, the paper has made a 12 weeks long BBS observation and recording study on coal miners, and comparatively analyzes the recorded for weekly average value of safety behavior index and the key behavior. In respect of unsafe psychology, the paper takes the current questionnaire about the miners' unsafe psychology, and takes Fuzzy Comprehensive Evaluation to evaluate the questionnaire results of two times to compare the level By comparing the data of coal miners' unsafe behavior and psychology, it is verified that the implementation of BBS is quite effective to reduce the incidence of accidents of coal miners.

Key Words: Behavior Based Safety (BBS), Coal Miners, Unsafe Behavior, Unsafe Psychological

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Introduction

Coal has always occupied an important position in China's sustainable and healthy economy development (Han SU *et al*., 2013). In recent years, because of the country put coal mine safety problems in the top priority, government policies and measures to coal mine safety and supervision have made great achievements, coal mine accident rate and the number of casualties has been reduced year by year (Choudhry RM, 2014; Li H *et al*., 2015). Due to the hard coal industry production environment, with coal mining over time, security risks gradually increased, coal mine safety problems occurs frequently (Koivupalo M *et al*., 2015). It is related to the life safety and property safety of the employees, and the production and development of the enterprise, and more related to the harmony and stability of the society (Yeow PHP *et al*., 2014). Therefore, it is urgent to solve the problem of coal mine safety.

Table 1 is the safety situation of coal mine in China in 2006-2015 (Schmitt N *et al*., 2016). China's coal mine safety situation is still not optimistic (Park CS *et al*., 2013).

The coal mine accidents happen with the three components which are about the unsafe behavior of employees, unsafe condition of equipment and facilities, and unsafe conditions of mining environment (Hollnagel E, 2014). As the main body of the coal mine production, the safety of people's behavior has a great relationship with the occurrence of the accident. The research domestic and overseas shows that the important cause of the accident is the unsafe behavior of human, which in the coal mining industry, the incidence rate of accidents is about 90% due to the unsafe behavior of human

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Table 1. Accidents and deaths of coal mine from 2006 to 2015 in China

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Number of accidents	2945	2420	1954	1668	1403	1201	779	589	509	344
Number of deaths	4746	3786	3215	2631	2433	1973	1384	1049	931	588

(Wachter JK *et al*., 2014). Therefore, the prevention and control of people's unsafe behavior is the focus of coal mine safety management.

And the unsafe behavior as the external performance, its most important decision factor lies in the person's psychology. Most of people's unsafe behavior is caused by people's unsafe insecurity (Fotopoulos CV *et al.,* 2013). Poor safety psychological state in the complex people - machine - environment is easy to lead to unsafe behavior, resulting in the occurrence of accidents. And in the accident, it can't be taken in a timely manner to actively and effectively remedial measures (Mooren L *et al.,* 2014). Therefore, it can further stimulate the enthusiasm of the staff production and reduce the occurrence of unsafe behavior, so as to improve the safety of coal mine enterprise productivity by the study of people's unsafe psychology.

As an important method to achieve the management of security pre control, BBS management has been continuously explored and researched by researchers. Stajkovic and Luthans (1997) has made a statistical research on the practice of BBS management from 70s to date. It is found that by using BBS management, the performance of the company has increased by 22%, and the effect of BBS management in the production enterprises is more obvious than that in the service enterprises. Geller (2002) believes that the necessary condition for BBS management to achieve obvious effect is employee participation. Meanwhile, the company's corresponding managers should also be included in the BBS management system, and actively support the whole BBS management plan. Sulzer-Azaroff (2000) believes that the key factors that influence the implementation of BBS management include implementation purpose, observation priority and frequency, feedback mechanism and support level, these factors will also directly affect the implementation effect. Gordon (2007) has studied the relationship between behavioral intervention effect and enterprise safety culture level. It is concluded that only when the safety culture of enterprises is matched with the objectives of BBS management, can the behavior intervention process be effectively guaranteed. By studying 8 companies implementing BBS management, Fang (2013) find that effective evaluation of the safety status and related atmosphere before the implementation of BBS management can reduce the interference and problems in the implementation process.

Methods

Research objects

As the main type of work in coal mining enterprises, coal miners' operation had great influence on coal mine safety, which has less behavioral requirements (Guo HL *et al*., 2013). And its behaviors can be easier to observe measure and record (Kirezieva K *et al*., 2013). So this paper main researches the object of coal miners.

In this paper, 30 people were randomly selected from the coal mining workers in Wang Zhuang coal mine, which were all adult men. And the paper made statistics about the age, length of

Table 2. The statistics data of coal miners

Features	Sample item	Sample number	Percentage	Cumulative Percentage
Age	20-30	12	40.0	40.0
	30-40	10	33.3	73.3
	40-50	8	26.7	100
Working years	≤5	5	16.7	16.7
	5-10	13	43.3	60.0
	≥10	12	40.0	100
Education	Primary school and below	13	43.3	43.3
	Junior middle school	12	40.0	83.3
	High school and above	5	16.7	100
Marital status	Unmarried	10	33.3	33.3
	Married	20	66.7	100
Participate in safety training number	≤5	12	40.0	40.0
	5-15	10	33.3	73.3
	≥15	8	26.7	100

service, education, marriage status, the number of participate in safety training, such as table 2.

Research method

Behavior-based safety management method

BBS, abbreviated form of Behavior-Based Safety, is a management method which carries out by establishing the difference between risk behavior and safe behavior, observing employees' behaviors, increasing employees' ability to initiatively respond, correcting employees' unsafe behavior, promoting the formation of security atmosphere, and improving safety performance in the production job site (Rocha R *et al*., 2015; Santos G *et al*., 2013).

BBS has a simple means and takes the behavior of the observed as the quantifiable standard (Qingguo MU *et al*., 2014). Additionally, the paper adopts the way of filling in the behavior record to observe and record the key behaviors of the staff. After conducting BBS analysis of the data, the paper constantly intervene the key behaviors of the on-site coal miners, and gives feedbacks and corrections in view of the situation, thus correcting the unsafe behavior in the aspect of specific behaviors, improving safe consciousness and building a harmonious and safe enterprise culture (Destri C, 2013; Waldén B *et al*., 2013). This paper is about the application and research of BBS management method in the coal mining enterprises.

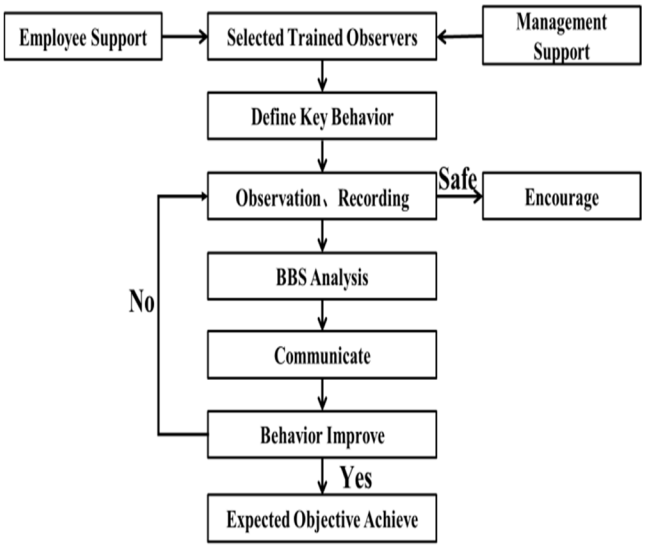

Figure 1. Work flow chart of BBS

BBS should accordance with certain procedures in order to ensure its smooth and effective implementation in the enterprise (Desmorat G *et al*., 2013). Figure 1 is the specific implementation process of BBS in the enterprise.

Fuzzy comprehensive evaluation

Fuzzy Comprehensive Evaluation is a comprehensive evaluation method based on fuzzy mathematics (Zhang J *et al.,* 2014). This method uses the Membership Degree Theory to transform the qualitative evaluation into quantitative evaluation by such process of selecting samples, determining the evaluation of the project set, evaluation criteria, evaluating the weight of the project, constructing factors evaluation matrix, and calculating the comprehensive evaluation vector and comprehensive satisfaction. It has the characteristics of clear evaluation results and strong logic, which can solve the problems of difficult to quantify and uncertainty (Zhang G, 2013; Akyuz E *et al*., 2014).

To judge the safety state of human's psychology is a relatively vague concept. On the other hand, security is a relative concept, which has the characteristic of uncertainty, so the quantitative research can only get a relatively fuzzy result (Chen CF *et al*., 2014). Therefore, it is feasible to evaluate the level of the unsafe psychology of the coal mining workers by the Fuzzy Comprehensive Evaluation Method in this paper.

Technology roadmap

Combining the specific case in Wangzhuang coal mine, according to the implementation process of BBS, and on the basis of doing a good preparation job and training work, this paper focused on coal miners for a observing and recording period of 12 weeks during the February 15, 2016 - May 6, 2016.

Observation process was divided into three phases. The first observing stage was on February 15 - March 11, in the start of this stage, this paper took a questionnaire survey on the safety of coal mining workers. And it was only observed and recorded based on key behavioral factors without any behavioral intervention. The second observing phase was on March 14 - April 8, in this stage observers had a greater participation for the actual operation of the coal miners according to the data compiled and analyzed from the results of the first phase. It should be stopped, communicated and corrected in time when the unsafe behavior that occurred during the work. The third observing stage was April 11 - May 6, observers continued to observe

and record the coal miners' behaviors, refraining from any further acts of intervention. At the end of this phase, a further investigation of the unsafe psychological questionnaire was conducted again.
In terms of unsafe behavior, this paper tested and verified the improve situation of the coal miners' unsafe behaviors by comparing its effectiveness though the statistics and analysis of the three-stage data after the observation. In terms of unsafe psychological, this paper compared the evaluation results of the two unsafe psychological evaluation questionnaires, and then obtained the improvement of the safety psychology of the coal mining workers.

Study on the Influence of BBS on Unsafe Behavior

The application of BBS in the management of unsafe behavior

Set up a leading group

Before the study, a 10 people BBS leadership team had been set up by three corporate leaders, five department heads who are responsible for coal production safety work production, two experienced shearer drivers.

Define key behaviors

Key behavior is the risky behavior which often occurs in the production process and likely to cause accidents. Most of the key behaviors are detailed and unconscious. In behavioral safety management, it needs to define the key behaviors as the basis for the behavior observing.
But how can define the key behaviors? This paper ensured the accuracy of the key behaviors definition by combining several ways such like analysis of accident statistics over the years, coal mine accident research reports, recording of illegal command, illegal operations and violations of labor discipline, coal miner workflow and safety practices. And it refers to site safety inspection results; soliciting the observations and recommendations from the corporate leaders, department heads, security administrators and coal miners. With the specific circumstances, define the key behaviors in Table 3 under the premise of observable and measurable.

Select and train observers

This paper selected Total 5 person from the security administrators and representative coal miners as observers, then trained them before observing. Training included: how to begin to observe and observe correctly, and fill in the behavior observation record sheet correctly, the implementation process, BBS model and analysis, communication and correction of unsafe behaviors, etc.

It aimed to make the behavior observers have in-depth understanding of behavioral safety observation method by BBS training, which was conducive to the effective implementation of behavior management measures.

Observe and record

The experiment needs to be open explicit observing and recording. Notes are as follows: 1) Introduce themselves to the coal miners at the beginning of observation.

Do not disturb their normal work. Do not interrupt the coal miners when they are doing the dangerous operations, and then intervene when it is not in a dangerous state. 2) When the observed behaviors seriously endanger the human's life, health or the environment, it should be promptly stopped. In this situation, the observers should

Table 3. Key behaviors observation table of coal miners

NO.	Key behavior	Specific content
1	The safe use of protective equipment	Helmets, seat belts and other protective equipment are used and using correctly
2	Checking the tools, equipment for security	Confirm the security, the safe using state, the reasonable using of tools and equipment
3	Hanging beam safety	Carefully check the reinforcement support, coal rib and the situation of the pillar rope. Operate according to the operation process under the condition of prepared supporting materials, tools, horizontal pin ,etc.
4	Using coal shovel rightly	Re treatment the dangerous side and Umbrella eaves. Lay a solid (temporary) post and clean remaining coal facing chute. Personnel may not work on top of the air. Do not execute finger oral
5	Normal sliding and supporting	Check the temporary pillar in front and surrounding support to confirm the temporary and surrounding support security and reliability. Move in place or pillar by line. No transport in chute pushing head and use circular slip failure pillar
6	Prop drawing normally	Pillar for the two injections and reinforcement around the support. It is strictly prohibited that any part of the body goes into the mined out area to pick up the material and the sub range is not up to the requirements of the provisions.
7	Attention to the operation of the unit and the stop signal	Attention to the operation of the unit and the stop signal at any time. (Shouting or shaking lights)
8	Reporting when upon the mine	Performing handover procedures and filling the work records.

not continue to follow the observation schedule. The observers should first stop that dangerous behavior, and immediately communicate with the coal miners for discussion of the behavior. 3) Fill in the data table of the results which had to be observed at any time. Data table should be turned in the next day. At the end of each stage it should pride a summary and then form a written document.

Analysis on the unsafe behavior improvement of BBS

At the end of three experimental stages, this paper summarized and finished the behavioral safety observation table, then made analysis on the result of safety behavior index.

Depending on the formula of security level,$S_I = N_1/(N_1 + N_2)$, this paper defined the S_I as the level of safety index, the N_1 as the number of safe behaviors, the N_2 as the number of unsafe behaviors, and the N_1+N_2 as the number of the total number of observing behaviors. This paper chose the S_I to represent the security level of the coal miners' operation. In the total number of behavior remain unchanged, while increasing the number of coal miners' unsafe behaviors, the S_I value decreases; and while decreasing the number of coal miners' unsafe behaviors, the S_I value increases.

Comparative analysis of weekly average

According to the results summary of behavioral safety observation sheets, this paper did a security level weekly average index statistics, and obtained safety behavior index of coal miners during the observation period. The result is shown in table 4.

Do the S_I value change line chart from the first week to the twelfth week in the observation period according to the above table, as shown in Figure 2.

It can be concluded that in the initial observing four weeks coal miners had more frequently unsafe practices. S_I values were between 50% and 60%. In the second phase of the experiment, due to the observers' interventions and communication with the miners' related behaviors, in the second phase the level of safety had significantly improved. S_I values gradually increased to about 80%. In the third experimental phase, the experimental withdrawn the behavioral intervention, S_I values showed a decreasing trend. But this time the S_I value was still about 20% higher than the base period.

Table 4. Safety level index of coal miners during the observation period

Phase	Observation week	N_1	N_2	N_1+N_2	S_I
The first stage	The 1st week	31.2	26.2	57.4	54%
	The 2nd week	30	23.8	53.8	56%
	The 3rd week	31.4	24.8	56.2	56%
	The 4th week	30.2	23	53.2	57%
The second stage	The 5th week	40.8	13.6	54.4	75%
	The 6th week	42	11	53	79%
	The 7th week	44.6	10.4	55	81%
	The 8th week	47.6	7.4	55	87%
The third stage	The 9th week	41	13.4	54.4	76%
	The 10th week	43	12.6	55.6	77%
	The 11th week	42.4	11.6	54	78%
	The 12th week	42.2	14	56.2	75%

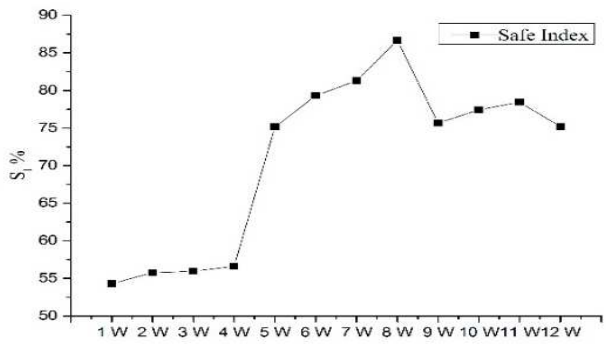

Figure 2. Safety levels during the observation period

As can be seen in Table 1, the mean gender of the participants was 55.5% male and 44.5% female with a mean age of 32.9 (SD= 2.8) years. They all had a good job (50% students, 16.7% employee, 33.3% other).

Comparative analysis of key behaviors

In connection with these eight key behaviors, this paper had the total number statistics of the unsafe behaviors and the safe behaviors at the first week and the twelve week, and obtained the S_I values of the key behaviors. Statistical results are shown in table 5.

According to statistics, S_I value contrast histogram between the 1st week and the 12th week

of coal miners' key behaviors was shown in Figure 3.

The figure showed that the level of safety critical behavior had improved overall. Wherein the safe use of protective equipment, hanging beam safety, prop drawing normally, attention to the operation of the unit and the stop signal of the unit signals the four key behaviors increase faster, respectively increased by 46%, 35%, 27% and 23%.

Use SPSS software to do paired sample test for differences according to the key behaviors of the first week and 12 weeks S_I value, and the results of the analysis are shown in Table 6.

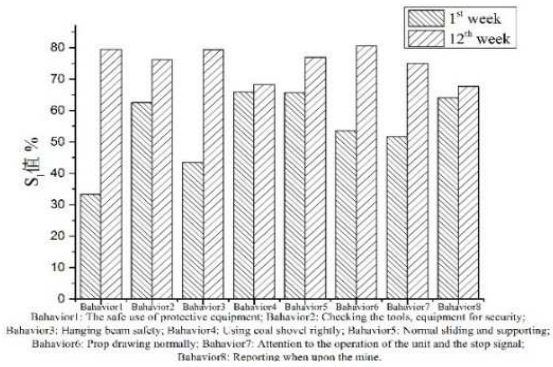

Figure 3. S_I value contrast histogram of key behaviors

Table 5. S_I value at the beginning and end of key behaviors

NO	Key behavior	S_I of the 1st week	S_I of the 12th week
1	The safe use of protective equipment	33.33%	79%
2	Checking the tools, equipment for security	62.5%	76%
3	Hanging beam safety	43.59%	79%
4	Using coal shovel rightly	65.85%	68%
5	Normal sliding and supporting	65.63%	77%
6	Prop drawing normally	53.57%	81%
7	Attention to the operation of the unit and the stop signal	51.61%	75%
8	Reporting when upon the mine	64.1%	68%

Table 6 shows the paired samples T-test results of the 1st week and the 12th week. It can study that the samples critical confidence level is 0.007, much less than the 5% significance level. Then reject the null hypothesis, indicating that the experiment caused a significant change in the value of S_I. In the first week to the 12th week thoughtful coal miners' behaviors improved significantly, which could validate that BBS has a significant effect on improving enterprise production safety.

Study on the Influence of BBS on Unsafe Psychology

This paper uses the Miners' Unsafe Psychological Scale which is revised by LI Naiwen (Naiwen Li *et al.*, 2010). In order to improve the accuracy and the recovery rate, and to ensure that the results consistent with the working state of coal miners, the questionnaire was used to fill in the instant which use the time of meeting and completed on the spot.

The paper carries out the questionnaire survey twice before and after the BBS implementation. Then it takes Fuzzy Comprehensive Evaluation to evaluate and analyze the results.

Determine the evaluation project set

The scale included 6 terms of security sense of helplessness, 5 terms of reverse psychology, 5 terms of mental paralysis and 4 terms of temporary psychology. Positive scoring method was used in the scale.

According to the miners' unsafe psychological scale, the scale index system was divided into two layers in order to use the two level fuzzy comprehensive evaluations. The one and two level indicators are classified as table 7.

Determine the evaluation criteria

The scale used the 5 level scoring methods. Evaluate sets e= {e1, e2, e3, e4, e5} = {nil, lesser, commonly, biased, serious}, which 1 points on "nil", 5 points on "serious".

Determine the weight of the project

The weight of the first class index and second class index carried out by Delphi method. As shown in Table 8.

Table 6. Paired sample test table

		Paired difference					T	DOF	Significant (two-tailed)
		Average Value (E)	Standard deviation	Standard error of the mean	95% confidence interval of the difference				
					Lower limit	Upper limit			
Pair 1	The 1st week-12th week	-20.3901	15.52015	5.4872	-33.3653	-7.41496	-3.716	7	0.007

Table 7. One and two level index classification

First class index	Second class index	Item
Security sense of helplessness	Due to risk of helplessness	1, 2, 4, 6
	Due to existence of helpless	3, 5
Reverse psychology	Due to differential treatment	7, 8, 9, 10
	Due to monotonous rude	11
Mental paralysis	Due to habit of experience	12, 13, 15
	Due to lack of awareness	14, 16
Temporary psychology	Due to work content	17, 19, 20
	Due to work safety	18

Table 8. The indicators and weights of the unsafe psychological scale

First class index	Weight	Second class index	Weight
Security sense of helplessness	0.32	Due to risk of helplessness	0.69
		Due to existence of helpless	0.31
Reverse psychology	0.21	Due to differential treatment	0.83
		Due to monotonous rude	0.17
Mental paralysis	0.23	Due to habit of experience	0.54
		Due to lack of awareness	0.46
Temporary psychology	0.24	Due to work content	0.38
		Due to work safety	0.62

Statistics and analysis of the survey results

Analysis of the first survey results

Statistics of the survey results

A total of 30 valid questionnaires were collected in the unsafe psychological measurement. After the withdrawal of the questionnaires, the results of the first questionnaire survey were carried out, such as table 9.

Measure the security status of the second class index. The safety status of coal miners was judged by the scores of each item according to the statistics of the results on the above table. Survey information statistics of evaluation indexes were shown as table 10.

Second level evaluation of scale

Using the questionnaire survey to collect the safety psychological data of coal mining workers, the evaluation matrix was obtained through the summary statistics.

$$W1 = (0.69\ 0.31)$$

$$R_1 = \begin{pmatrix} 0.11 & 0.15 & 0.25 & 0.37 & 0.12 \\ 0.05 & 0.14 & 0.28 & 0.43 & 0.1 \end{pmatrix}$$

$$B1 = W1 * R1 = (0.0914\ 0.1469\ 0.2593\ 0.3886\ 0.1138)$$

Similarly,

$$B2 = (0.0715\ 0.1664\ 0.3079\ 0.2834\ 0.1708)$$

$$B3 = (0.0746\ 0.1524\ 0.3186\ 0.3390\ 0.1154)$$

$$B4 = (0.0586\ 0.1004\ 0.2650\ 0.2600\ 0.3160)$$

Table 9. The results of the first questionnaire survey

First class index	Second class index	Nil	Lesser	Commonly	Biased	Serious
Security sense of helplessness	Due to risk of helplessness	10.83%	15.00%	25.00%	37.50%	11.67%
	Due to existence of helpless	5.00%	13.33%	28.33%	43.33%	10.00%
Reverse psychology	Due to differential treatment	7.50%	18.33%	33.33%	28.33%	12.50%
	Due to monotonous rude	3.33%	10.00%	20.00%	30.00%	36.67%
Mental paralysis	Due to habit of experience	6.67%	17.78%	35.56%	27.78%	12.22%
	Due to lack of awareness	8.33%	11.67%	26.67%	41.67%	11.67%
Temporary psychology	Due to work content	4.44%	14.44%	42.22%	25.56%	13.33%
	Due to work safety	6.67%	6.67%	16.67%	26.67%	43.33%

Table 10. Survey information statistics of evaluation indexes

First class index	Second class index	Nil	Lesser	Commonly	Biased	Serious
Security sense of helplessness	Due to risk of helplessness				√	
	Due to existence of helpless				√	
Reverse psychology	Due to differential treatment			√		
	Due to monotonous rude					√
Mental paralysis	Due to habit of experience			√		
	Due to lack of awareness				√	
Temporary psychology	Due to work content			√		
	Due to work safety					√

Table 11. The results of the second questionnaire survey

First class index	Second class index	Nil	Lesser	Commonly	Biased	Serious
Security sense of helplessness	Due to risk of helplessness	11.67%	28.33%	40.83%	11.67%	7.50%
	Due to existence of helpless	10.00%	53.33%	21.67%	11.67%	3.33%
Reverse psychology	Due to differential treatment	8.33%	33.33%	30.00%	15.00%	13.33%
	Due to monotonous rude	10.00%	16.67%	23.33%	40.00%	10.00%
Mental paralysis	Due to habit of experience	43.33%	20.00%	16.67%	11.11%	8.89%
	Due to lack of awareness	11.67%	46.67%	23.33%	8.33%	10.00%
Temporary psychology	Due to work content	15.56%	32.22%	25.56%	20.00%	6.67%
	Due to work safety	20.00%	23.33%	40.00%	6.67%	10.00%

First level evaluation of scale

$$B=\begin{pmatrix}B_1 & B_2 & B_3 & B_4\end{pmatrix}^T$$

$$=\begin{pmatrix}0.0914 & 0.1469 & 0.2593 & 0.3886 & 0.1138\\ 0.0715 & 0.1664 & 0.3079 & 0.2834 & 0.1708\\ 0.0746 & 0.1524 & 0.3186 & 0.3390 & 0.1154\\ 0.0586 & 0.1004 & 0.2650 & 0.2600 & 0.3160\end{pmatrix}$$

$$W=(0.32\ 0.21\ 0.23\ 0.24)$$

$$S=W*B$$

$$=(0.32\ \ 0.21\ \ 0.23\ \ 0.24)\begin{pmatrix}0.0914 & 0.1469 & 0.2593 & 0.3886 & 0.1138\\ 0.0715 & 0.1664 & 0.3079 & 0.2834 & 0.1708\\ 0.0746 & 0.1524 & 0.3186 & 0.3390 & 0.1154\\ 0.0586 & 0.1004 & 0.2650 & 0.2600 & 0.3160\end{pmatrix}$$

$$=(0.0755\ \ 0.1411\ \ 0.2845\ \ 0.3242\ \ 0.1747)$$

The level of psychological safety of the coal miners was determined "biased" by b_4=0.3242 according to the maximum membership principle. Namely, the coal miners' psychological safety was in an unhealthy state, which needed to be prevented and corrected.

Analysis of the second survey results

After the implementation of BBS, the paper carried out the second unsafe psychological test to the coal miners. And the results of the questionnaire statistics were such as table 11.

Do the second level evaluation and first level evaluation of the results of the survey by using the fuzzy comprehensive evaluation method, with the same analysis step of the first survey results. The formulas were as follows

$$B'=\begin{pmatrix}0.1138 & 0.3575 & 0.3511 & 0.1131 & 0.0645\\ 0.0834 & 0.3111 & 0.2881 & 0.1925 & 0.1249\\ 0.2874 & 0.3242 & 0.1976 & 0.0962 & 0.0946\\ 0.1810 & 0.2642 & 0.3468 & 0.1194 & 0.0886\end{pmatrix}$$

$$S'=W*B'$$

$$=(0.32\ \ 0.21\ \ 0.23\ \ 0.24)\begin{pmatrix}0.1138 & 0.3575 & 0.3511 & 0.1131 & 0.0645\\ 0.0834 & 0.3111 & 0.2881 & 0.1925 & 0.1249\\ 0.2874 & 0.3242 & 0.1976 & 0.0962 & 0.0946\\ 0.181 & 0.2642 & 0.3468 & 0.1194 & 0.0886\end{pmatrix}$$

$$=(0.1635\ \ 0.3177\ \ 0.3015\ \ 0.1274\ \ 0.0899)$$

The level of psychological safety of the coal miners was determined "lesser" by b_2'=0.3177 according to the maximum membership principle. It showed that the implementation of BBS had a significant effect on the safety of coal miners when compared with the results of the first survey.

Conclusions

(1) Coal miner is an important type of work of Wangzhuang Coal Mine, of which the safety operation is of great influence on the coal mine. Moreover, such work type behavior has strong measurability, contributing to the observation and record of BBS. Therefore, coal miner is chosen as the main research subject.

(2) BBS is an effective way to improve coal miners' safety behavior. After canceling the BBS behavior intervention, S_I value witnesses a 20% increase than that in the base period, in which safety use of protective equipment and other three key behaviors are highly improved. Furthermore, it is verified that key behaviors of coal miners are improved obviously by a difference examination.

(3) Safety psychology level of coal miners can be enhanced when BBS is improving their safety behaviors. The paper carries out the questionnaire survey twice. It is found that safety psychology level of coal miners is improved to "lesser" from "biased", thus verifying the effect of BBS on improving coal miners' safety psychology.

(4) To fundamentally solve the unsafe problems of the enterprises, it is a must to carry out the experimental recirculation of BBS. After observing and intervening the key behaviors, it is required to finish related materials, reflect on the problems discovered in the experiment, redefine the key

behavior according to the situation, and make intervention to coal miners in such way.

(5) Further research on the corresponding relationship between the psychology and behavior of the coal miners is suggested. Psychological performance is closely related to behavior. Careful observation and study of the relationship between them can further control the occurrence of unsafe events.

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