Application of Data Analysis in Risk Management and Control of Medical Waste Treatment Workshops

-Analysis and Control of the Safety Risk Data
Safety Risk Data Analysis of Medical Waste Treatment Workshops

Huifen Wang[1], Shuai Liu[2], Tangxiao Yuan[3]*, Leilei Zhai[4]

[1]188015065@qq.com, [2]351853610@qq.com, Corresponding author's e-mail: [3]*yuantx@njust.edu.cn, [4]1600052560@qq.com

School of Mechanical Engineering, Nanjing University of Science and Technology, Nanjing 210094, China

Abstract. In the post-epidemic era, the workload of medical waste disposal workshops is still huge, and it is necessary to ensure the safety of medical waste disposal personnel in various aspects. In order to explore the potential safety risks in the medical waste disposal workshop (MWDW), find out the key factors, and reveal the cause of accidents in the medical waste disposal workshop. In this paper, the HFACS-MWDW model suitable for analyzing MWDW is constructed on the basis of the Human Factors Analysis and Classification System (HFACS) method, and the causal analysis of MWDW is carried out from four levels: unsafe behavior, unsafe behavior premise, unsafe supervision, and organizational influence. The chi-square test ($\chi 2$) and odds ratio (OR) were used to analyze the causal relationship between the upper and lower levels. Based on this method, 205 accident reports of medical waste disposal workshops were analyzed as samples, and it was found that the more common causative factors in medical waste workshops were organizational process, failure to correct known problems in time, personnel factors and mistakes; the correlation strength was obtained And the largest accident-causing path is: operation management→unreasonable work arrangement→capacity limitation→decision-making error, the total OR value is 14.755. Finally, based on the analysis results, countermeasures to prevent potential security risks in MWDW are proposed. The results show that: the organizational impact is mainly reflected in human resources and operation management; Unsafe supervision is mainly reflected in insufficient attention to supervision work and inadequate investigation of hidden dangers; The premise of unsafe behavior is mainly reflected in insufficient personal preparation, improper technical environment and team management; Safety behaviors focus on skill-type errors and decision-type errors.

Keywords: Medical Waste Disposal Workshop (MWDW); Human Factors Analysis and Classification System (HFACS); Accident Causes; Safety Risks

1 Introduction

As the concept of overall national security concept continues to be mentioned and valued, it emphasizes the need to attach importance to both homeland security and national security

BDEDM 2024, January 12-14, Ningbo, People's Republic of China
Copyright © 2024 EAI
DOI 10.4108/eai.12-1-2024.2347246

internally, and to embark on a national security path with Chinese characteristics [1]. The rapid development of society has promoted the continuous improvement of the medical service system, and the output of medical waste is also increasing day by day. Medical waste treatment is an indispensable link in the medical process. However, medical waste treatment workshops involve complex operating processes, personnel behaviors and management measures, and there are potential safety risks [2]. These risks can cause significant harm to shop floor personnel. In particular, human operating errors bring huge challenges to the safe production of medical waste treatment. Therefore, analyzing the causes of accidents involving personnel in the medical waste treatment process from the perspective of human factors can improve production efficiency and quality, and provide guidance for the medical waste treatment workshop. Provide scientific basis and preventive guidance for safe production [3].

The disposal technology of medical waste treatment workshops adopts the method of "steam or microwave sterilization + incineration", as shown in Figure 1. During the production process, there are many dangerous factors, such as high temperature burns, falls from high altitudes, and fires and explosions caused by hazardous chemicals. , radiation hazards, environmental pollution and toxic and harmful gas poisoning and other accidents [4-5]. To ensure the personal safety and health of workers, practical measures must be taken.

Figure 1: Medical waste disposal site.

Nowadays, a variety of data analysis methods are used for human factors analysis. For example, in 2019, Adam Hulme [6] proposed the Hierarchical Task Analysis for Human Error Assessment and Reduction Technique (HEART) analysis layering The concept of task identification of errors and improvement opportunities provides a powerful method for safety research and accident analysis in different fields; In 2023, Miao Chunxin[7] used the Swiss Cheese Model for the first time to help the refined management of medical waste better identify and respond to engineering risks, improve the quality of medical waste management, and ensure safety and effectiveness; in 2023, Zhong Jiangping[8] A SHEL (Staff, Hardware, Environment, and Task) model was established to analyze the Shanghai practice of emergency treatment of medical waste under special circumstances; 2015 , Li Wenjun [9] proposed the concept of event tree and fault tree analysis, revealing the causes by constructing a structure, and combined with Bayesian network to analyze the risk impact of operator errors. The Human Factors Analysis and Classification System (HFACS) model [10] is an effective method for analyzing human organizational factors in production activities. It can not only analyze human errors that cause risks, but also discover potential risks in the organizational environment. factors, which have not been widely used in risk analysis of medical waste treatment workshops. Therefore, this article uses empirical research methods to introduce the HFACS model into the personnel risk management of medical waste treatment workshops. By combining the HFACS model with the actual situation of medical waste treatment workshops, it deeply explores potential safety hazards and provides targeted guidance measures to improve the safety management level of medical waste treatment workshops.

2 Analysis of causes of hfacs-mwdw accident

This study analyzed workshop accident reports from a medical waste treatment enterprise in East China in the past 10 years, with a total of 865 accident samples. Based on sample statistics, common factors leading to accidents were identified, and combined with the definition of causes, a HFACS-MWDM model of human-organizational causes of accidents in medical waste treatment workshops was proposed. According to the characteristics of the accident, the causative factors were divided into 4 levels, involving a total of 23 factors, of which sub-factors occurred a total of 13820 times. See Table 1 for detailed classification statistics.

Table 1: Classification statistics of MWDM accident causative factors.

<table>
<tr><th>Causative Layer</th><th colspan="2">Cause of Accident</th><th>Frequency</th><th>Proportion = frequency/sum of sub-factors</th></tr>
<tr><td rowspan="8">Organizational Impact (A)</td><td rowspan="2">resource management</td><td>Human Resources (A1)</td><td>870</td><td>6.30%</td></tr>
<tr><td>Equipment resources (A2)</td><td>829</td><td>6.01%</td></tr>
<tr><td rowspan="3">organizational climate</td><td>Corporate Culture (A3)</td><td>210</td><td>1.52%</td></tr>
<tr><td>Organizational Structure (A4)</td><td>120</td><td>0.87%</td></tr>
<tr><td>Rules and Regulations (A5)</td><td>701</td><td>5.07%</td></tr>
<tr><td rowspan="3">organizational process</td><td>Operating Standards (A6)</td><td>640</td><td>4.63%</td></tr>
<tr><td>Operations Management (A7)</td><td>1289</td><td>9.35%</td></tr>
<tr><td>Risk Management (A8)</td><td>830</td><td>6.01%</td></tr>
<tr><td rowspan="4">Unsafe Supervision (B)</td><td rowspan="2">Insufficient supervision</td><td>Lack of supervision system (B1)</td><td>270</td><td>1.96%</td></tr>
<tr><td>Not paying enough attention to supervision (B2)</td><td>982</td><td>7.10%</td></tr>
<tr><td>Inappropriate planned tasks</td><td>Unreasonable work arrangements (B3)</td><td>380</td><td>2.75%</td></tr>
<tr><td>failure to correct known issues in</td><td>Failure to investigate hidden dangers (B4)</td><td>889</td><td>6.45%</td></tr>
</table>

Causative Layer	Cause of Accident		Frequency	Proportion = frequency/sum of sub-factors
	a timely manner	Safety issues were not dealt with in a timely manner (B5)	425	3.04%
	supervise violations	Intentional violation of supervision regulations (B6)	334	2.46%
Prerequisites for Unsafe Behavior (C)	personnel factors	Lack of personal preparation (C1)	678	4.93%
		Improper management of team resources (C2)	702	5.07%
	operator status	Health status (C3)	110	0.80%
		Capability limitations (C4)	543	3.91%
	envirnmental factor	Physical environment (C5)	234	1.74%
		Technical environment (C6)	815	5.87%
Unsafe behavior (D)	mistake	Skill error (D1)	570	4.13%
		Decision-making errors (D2)	910	6.59%
	violation	Violation of institutional rules (D3)	470	3.41%

3 Correlation analysis between upper and lower layers of hfacs-mwdw

3.1 Chi-square independence test and odds ratio analysis

In 1900, British statistician Karl Pearson first proposed the chi-square test [11], and its statistic is:

$$\chi^2 = \sum_i^k \frac{(O_i - F)^2}{F_i} \tag{1}$$

Among them, O_i is the observed frequency at level i, and F_i is the expected frequency at level i.

Chi-square test (χ2) is a commonly used hypothesis testing method suitable for categorical and ordinal variables. It is widely used in multi-disciplinary fields to explore the correlation between variables. The process of exploring whether there is an association between two categorical variables is called the chi-square test of independence. Because the variables in the correlation analysis of human factors in medical waste disposal accidents studied in this article are categorical data, they can be explored using the chi-square independent test [12].

Since this article only analyzes the correlation between adjacent levels of factors, it only involves exploring the relationship between two categorical variables[13]. The sample frequency contingency table can be expressed as a 2×2 independent sample four as shown in Table 2 below. Table, where a, b, c, and d respectively represent the actual observation frequencies under factor conditions.

Table 2: 2×2 Column Table of χ2.

		Upper level factors		sum of rows
		Y	N	
underlying factors	Y	a	b	a+b
	N	c	d	c+d
column sum		a+c	b+d	n=a+b+c+d

The simplified calculation formula of χ2 is:

$$\chi^2 = \frac{n(ad-bc)^2}{(a+b)(c+d)(a+c)(b+d)} \tag{2}$$

This indicator is used to measure the difference between actual observed values and theoretical values. From its size, the probability level of epistatic factors that can trigger the emergence of low-level factors in the HFACS model framework can be inferred. For a 2*2 contingency table, the odds ratio (OR) is calculated as follows:

$$OR = \frac{ad}{bc} \tag{3}$$

Odds ratio (OR), also known as odds ratio, is a statistical analysis method used to measure whether there is a correlation between the occurrence of two types of factors in a specific group. The odds ratio was initially widely used in the medical field to study the correlation between risk factors and diseases. Later, with the deepening of research, it was gradually extended to many engineering fields [14]. Usually, we use the size of the OR value to measure the possibility of upper-level factors inducing the occurrence of lower-level factors. When the OR value is greater than 1, it means that the occurrence of upper-level factors can increase the probability of the occurrence of lower-level factors. When the OR value is less than 1, it means that the upper-level factors There is no necessary connection between the emergence of and the emergence of underlying factors [15].

This article uses Python to conduct chi-square test and OR analysis on the causative factors in the HFACS-MWDW framework of 205 medical waste disposal accident records, and calculate the values of $\chi2$, P and OR. When P < α (this article assumes α = 0.05, common significance levels include 0.05, 0.01, and 0.10, among which 0.05 is the most commonly used), the statistics of results with significant correlation when the OR value is greater than 1 are shown in Table 3.

Table 3: Statistics of correlation analysis results (P<0.05 and OR>1).

Causative Factors	Chi-square test		OR	95% confidence interval	
	x^2	p		lower limit	upper limit
Organizational Influence Level (A) * Insecure Supervision Level (B)					
Human resources (A1) * supervision work is not paid enough attention (B2)	16.617	0.000	3.269	1.833	5.829

Human resources (A1) * work arrangement is unreasonable (B3)	4.561	0.033	2.158	1.055	4.411
Equipment resources (A2) * Insufficient troubleshooting (B4)	8.185	0.004	2.284	1.291	4.040
Corporate Culture (A3) * Deliberate violation of supervision regulations (B6)	8.383	0.004	3.914	1.474	10.392
Rules and Regulations (A5) * Lack of Supervision System (B1)	11.483	0.001	4.009	1.723	9.330
Operating standards (A6) * Lack of supervision system (B1)	8.576	0.003	3.291	1.439	7.526
Operating standards (A6) * Insufficient attention to supervision (B2)	11.842	0.001	2.898	1.565	5.367
Operation management (A7) * unreasonable work arrangements (B3)	14.010	0.000	3.202	1.719	5.963
Unsafe Supervision Level (B) * Prerequisite Level for Unsafe Behavior (C)					
Not paying attention to supervision (B2) * lack of personal preparation (C1)	16.055	0.000	3.418	1.849	6.316
Not paying attention to supervision (B2) * Improper team management (C2)	4.938	0.026	1.935	1.077	3.474
Supervision work does not pay attention to (B2) * ability limitations (C4)	6.751	0.009	2.311	1.219	4.381
Unreasonable work arrangements (B3) *Insufficient personal preparation (C1)	4.242	0.039	2.106	1.027	4.317
Unreasonable work arrangements (B3) * health status (C3)	9.981	0.002	6.075	1.748	21.117
Unreasonable work arrangements (B3) * Ability limitations (C4)	10.629	0.002	3.275	1.569	6.836
Inadequate investigation of hidden dangers (B4) * technical environment (C6)	10.752	0.001	2.590	1.458	4.601
Security issues were not dealt with in a timely manner (B5) *Physical environment (C5)	4.829	0.028	2.691	1.085	6.675
Security issues were not dealt with in a timely manner (B5) * technical environment (C6)	18.571	0.000	4.630	2.227	9.624
Prerequisite level of unsafe behavior (C) * Unsafe behavior level (D)					
Lack of personal preparation (C1) * skill-based mistakes (D1)	37.622	0.000	7.413	3.755	14.632
Improper team management (C2) * decision-making errors (D2)	4.653	0.031	1.895	1.057	3.400
Improper team management (C2) * violation of system rules (D3)	4.294	0.038	2.005	1.032	3.895
Health status(C3) *Skill error(D1)	11.118	0.001	5.378	1.827	15.834
Ability limitations (C4) *decision-making errors (D2)	13.018	0.000	3.215	1.679	6.156

[a] "*" indicates the influence of high-level factors and low-level factors.

3.2 Result analysis

After statistical analysis of the research results, the correlation between adjacent factors can be summarized as shown in Figure 2:

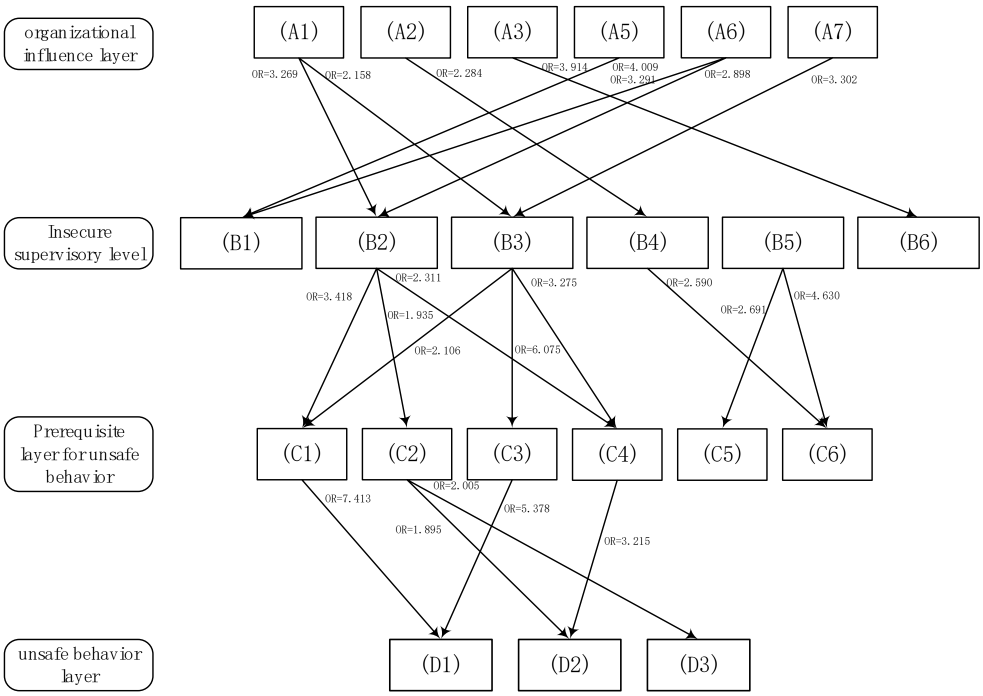

Figure 2: Influence relationship among various factors.

In Figure 2, if there is a directed arrow between two factors, then there is a causal relationship between the head and tail of the arrow. According to the causal relationship diagram in Figure 2, 14 complete causal chains can be summarized:

By calculating the sum of the OR values of each path, it can be concluded that the accident cause path with the largest sum of correlation strengths is operations management (A7) → unreasonable work arrangements (B3) → capability limitations (C4) → decision-making errors (D2) , the total OR value is 14.755.

4 Preventive measures

Based on the analysis of the above 3.2 results, combined with the 14 complete accident cause paths and common factors of accidents, the following preventive measures are formulated, see Table4.

Table 4: Preventive Measures for Injury Accidents in Medical Waste Disposal Workshop.

causative factors	Precaution
organizational impact	1) Intelligent resource management: Use big data analysis to optimize organizational structure, rules and regulations, and operational management to improve decision-making efficiency. 2) Digital corporate culture construction: Use information platforms to convey corporate culture, strengthen employees' sense of responsibility and safety awareness, and cultivate positive cultural values through digital channels. 3) Virtualized emergency drills: Use virtual simulation systems to conduct emergency drills, and use big data technology to analyze drill data to improve employee learning and adaptability. 4) Digital warnings and inspections: Improve warning signs and signs through the information management system, and the EHS department uses big data to conduct regular inspections to improve operational accuracy and ensure real-time and effective safety signs.
unsafe supervision	1) Establish and improve a supervision system: ensure that the supervision process is clear and consistent with relevant regulations and standards. 2) trengthen supervision: Increase supervision to ensure that supervisors pay full attention to safety issues during medical waste treatment. 3) Regularly conduct hidden danger inspections and promptly handle safety issues: Establish a regular hidden danger inspection mechanism, take timely corrective measures when problems are discovered, and strictly implement the feedback system. 4) Severely punish those who deliberately violate supervision regulations: clarify the penalties for violations, and severely punish those who violate regulations to form a strong deterrent.
Prerequisites for unsafe behavior	1) Intelligent employee training and education: Utilize information management systems to regularly organize systematic medical waste treatment training, analyze employee training effects through big data, establish digital training files, and realize intelligent management of the training process. 2) Resource planning and workload optimization: Use big data to analyze task urgency and employee skills to formulate reasonable resource planning and workload allocation strategies. Ensure employees' work intensity is balanced. 3) Health status attention: Use information systems to track employee health status. Analyze potential causes of accidents through big data, optimize personal protective equipment, and provide mental health support to reduce potential risks. 4) Equipment and environmental maintenance: The information management system can be used for equipment operation monitoring, regular maintenance and updates to ensure normal operation of equipment and reduce the risk of equipment failure. Establish a digital maintenance manual to improve equipment management efficiency.
unsafe behavior	1) Regularly strengthen employee training and education: formulate an assessment system to improve their safety awareness. 2) Establish a clear decision-making process and division of responsibilities: ensure the accuracy and rationality of decisions and prevent decision-making errors. 3) Strengthen the publicity and training of rules and regulations: Enhance employees' compliance with rules and regulations and reduce violations of system rules.

5 In conclusion

This paper proposes an accident analysis model for medical waste treatment workshops based on HFACS (HFACS-MWDW) to address the problem of personal accident prevention in medical waste treatment workshops. Based on the analysis of the accident in Workshop 205, 23 causative factors at 4 levels were summarized and extracted. Among them, organizational processes, failure to correct known problems in a timely manner, personnel factors, and errors are common factors leading to accidents at all levels. Chi-square test and concession ratio analysis were used to conduct significance and correlation tests on the upper and lower level factors of the accident cause analysis model HFACS-MWDW in the medical waste treatment workshop. The influence relationship between the upper and lower level factors was obtained. There are 14 complete accident causes. Among them, the causative path with the largest sum of correlation strengths is operations management (A7) → unreasonable work arrangements (B3) → capability limitations (C4) → decision-making errors (D2).

Finally, the key causative paths, key causative levels and key factors of accidents in the medical waste treatment workshop are discussed, and countermeasures are proposed. Organizational influence is the key causative level, which has deep and indirect characteristics. Future research needs to conduct an in-depth analysis of upper-level management factors and improve, strengthen, and enhance safety management measures and strategies so that they can better achieve expected safety management goals.

References

[1] Xi Jinping: Adhere to the overall national security concept and follow the path of national security with Chinese characteristics. Xinhuanet. 2014-04-15

[2] Li Biao, Li Xuanzhang. Relevant persons in charge of the Joint Prevention and Control Mechanism of the State Council answered every question: The collection and transfer of medical waste generated by nucleic acid testing follow strict procedures [N]. Daily Economic News, 2022-04-07(002). DOI:10.28571/n.cnki.nmrjj.2022.001548.

[3] Huang Shishu. Research on the application of medical waste information management system in disposal centers [J]. Science and Technology Wind, 2022(30):43-45.DOI:10.19392/j.cnki.1671-7341.202230015.

[4] Li Xiaojun. Research on the Construction of Medical Waste Management System of YN Company[D]. Tianjin University, 2022.DOI:10.27356/d.cnki.gtjdu.2019.004457.

[5] Yan Weiqun. Research on medical waste logistics supervision system and technology based on RFID[D]. Shanghai Jiao Tong University, 2012.

[6] Hulme A, Stanton N A, Walker G H, et al. Accident analysis in practice: A review of Human Factors Analysis and Classification System (HFACS) applications in the peer reviewed academic literature[C]//Proceedings of the Human Factors and Ergonomics Society Annual Meeting. Sage CA: Los Angeles, CA: SAGE Publications, 2019, 63(1): 1849-1853.

[7] Miao Chunxin, Song Peiqin, Yuan Yongmei. Application of refined management in medical waste management [J]. Modern Medicine and Health, 2023, 39(22): 3947-3951.Zhang Yuhu, Fan Yu, Li Qingyi. Research on flight human errors based on SHEL model [J]. Trainer Aircraft, 2017(03):6-9.

[8] Zhong Jiangping, Ruan Jianbo, Li Chuanhua. Shanghai practice of emergency disposal of medical waste under special circumstances [J]. China Ecological Civilization, 2023(01):89-

90.Shappell S, Detwiler C, Holcomb K, et al. Human error and commercial aviation accidents: an analysis using the human factors analysis and classification system[M]//Human error in aviation. Routledge, 2017: 73-88.
[9] Gao Ning. Cause analysis of ship collision accidents based on HFACS and Apriori algorithm[D]. Dalian Maritime University, 2018.
[10] Cai Baojie, Shao Lei, Li Zhengjie. New robust Kalman filtering algorithm using chi-square test and Newton interpolation [J]. Journal of Air Force Engineering University (Natural Science Edition), 2020, 21(01): 38-43.
[11] Wang Dapeng, Yan Su, Wang Nan, et al. Analysis of smart fire protection industry based on chi-square test and rank sum test [J]. Fire Science and Technology, 2022, 41(11): 1594-1598.
[12] Li Jing, Cai Zhongjie, Ren Yuan, et al. Application of HFACS-MI improved model in human factors analysis of hazardous chemical storage accidents [J/OL]. Journal of Safety and Environment: 1-9 [2023-08-20]. https:/ /doi.org/10.13637/j.issn.1009-6094.2023.0214.
[13] Tan Xin, Guo Yutong, Zhang Fan, et al. Analysis of causes of unsafe aviation maintenance events based on chi-square test [J]. Aviation Computing Technology, 2021, 51(06): 51-54.
[14] Gao Ning. Cause analysis of ship collision accidents based on HFACS and Apriori algorithm[D]. Dalian Maritime University, 2018.
[15] Cai Baojie, Shao Lei, Li Zhengjie. New robust Kalman filtering algorithm using chi-square test and Newton interpolation [J]. Journal of Air Force Engineering University (Natural Science Edition), 2020, 21(01): 38-43.