Application of Models for Occupational Health Risk Assessment to a Resin Anchorage Production Workshop

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Abstract. Objective to take the occupational health risk assessment in a resin anchorage production workshop by three models for occupational health risk assessment, and explore a suitable risk assessment model for this kind of production unit. Methods the occupational health status and main chemical hazard factors of a resin anchorage production workshop were investigated. Qualitative risk assessment and semi-quantitative risk assessment (contact limit ratio method and comprehensive index method) were used for risk assessment, and the results were compared and analysed. Results Comparing with comprehensive index method, the evaluation result of qualitative risk assessment and contact ratio method were closer to each other, but there was a big difference between the two methods in the determination of phthalic anhydride. Conclusion the three risk assessment methods had their own merits and demerits, the evaluation results were also different. The semi-quantitative risk assessment-contact limit ratio method is more suitable for the occupational risk assessment in resin anchorage production workshop.

1. Introduction
Occupational health risk assessment is a process of comprehensively and systematically identifying and analyzing workplace risk factors and protective measures, qualitatively or quantitatively assessing the level of occupational health risk, and taking corresponding control measures [1]. In recent years, many scholars have applied different risk assessment models to assess occupational hazards [2-3], but there was few reports in the field of resin anchorage agent production.

2. Objects and Methods

2.1. Objects
The resin anchorage agent production workshop is located in Jinan City, Shandong Province, which belongs to a large ferrous metallurgical mine enterprise's mine and roadway branch. At present, there were 14 formal employees in the workshop, work for 8 hours a day and 5 days a week. Through on-site occupational hygiene investigation, we selected styrene, dibutyl phthalate and phthalic anhydride as main chemical harmful factors in the workplace.
2.2. **Occupational Health Survey**

The survey included production process, raw materials and accessories, basic situation of workers, occupational disease protection measures, personal protective articles, warning signs and occupational health management system, etc.

2.3. **Detection of Occupational Hazards**

Sampling according to “Specifications of air sampling for hazardous substances monitoring in the workplace” (GBZ 159-2004) [4], inspection method according to GBZ/T 300 series standard [5-7].

2.4. **Procedures for Occupational Health Risk Assessment**

Firstly, occupational hazard factors were identified, then hazard characteristics of hazard factors were assessed, contact index was calculated by contact factors, or exposure level was assessed by air concentration and empirical theoretical equation. Finally, risk assessment level was obtained. The evaluation results of different risk assessment methods were expressed by risk ratio grade, which was divided into 4 levels: 1 level: 0-0.25; 2 level: 0.26~0.50; 3 level: 0.51~0.75; 4 level: >0.75.

2.5. **Qualitative Risk Assessment Method**

Health hazards were classified according to risk (R value) or occupational exposure limit range, and exposure level was determined mainly according to the physical characteristics (dust or volatility) and usage of chemicals.

2.6. **Semi-quantitative Risk Assessment-Contact Limit Ratio Method**

First of all, hazard classification of chemical harmful factors was carried out. The classification could be based on the toxicity of the chemical harmful factor, or on the half lethal dose (LD50) and the half lethal concentration (LC50) of the acute toxicity test. Then the air concentration (E) was compared with the corresponding occupational exposure limits (OEL, including maximum allowable concentration, short-term allowable concentration and time-weighted average allowable concentration), and the exposure level was determined by the maximum value of E/OEL. Finally, the risk index was calculated to determine the risk level.

2.7. **Semi-quantitative Risk Assessment-Comprehensive Index Method**

The determination of hazard level was the same as that of contact ratio method. However, the determination of exposure level needed to take into account such factors as exposure limit ratio (E/OEL), vapor pressure or aerodynamic diameter of chemical substances, usage, contact time and hazard control measures (engineering protection measures, emergency rescue facilities, emergency rescue measures, personal protective articles and occupational health management).

3. **Results**

3.1. **Occupational Health Survey**

The production process of this workshop was the general mode of resin anchorage agent production in the surrounding area, which was typical and representative. The workshop was a small-scale production, raw materials and accessories blanking, filling and packaging were all manual operations. The production process mainly included ingredients (curing agent ingredients, cement ingredients), mixing, filling (curing agent filling, cement filling) and packaging. The main occupational hazards were silica dust, other dust, styrene, dibutyl phthalate, phthalic anhydride and noise.

3.2. **Test results of occupational hazards**

The posts of occupational hazard risk assessment were curing agent filler, cement filler and finished product packer. The results are shown in Table 1.
Table 1. Test Results of Occupational Hazards in an Anchorage Agent Workshop.

| Positions       | Occupational Hazardous Factors | Air Detection Concentration (mg/m³) | Occupational Exposure Limits/OEL (mg/m³) | E/OEL |
|-----------------|---------------------------------|------------------------------------|----------------------------------------|-------|
| Curing Agent    |                                 |                                    |                                        |       |
| Bottling        | Styrene                         | 14.6-18.7                          | 50                                     | 0.37  |
|                 | Dibutyl phthalate               | 38.8-53.2                          | 2.5                                    | 21.28 |
|                 | Phthalic anhydride              | <0.03                              | 1                                      | <0.03 |
| Cement Filler   |                                 |                                    |                                        |       |
|                 | Styrene                         | 12.8-16.3                          | 50                                     | 0.33  |
|                 | Dibutyl phthalate               | 40.7-55.0                          | 2.5                                    | 22.00 |
|                 | Phthalic anhydride              | <0.03                              | 1                                      | <0.03 |
| Product Packing |                                 |                                    |                                        |       |
|                 | Styrene                         | 10.8-13.5                          | 50                                     | 0.27  |
|                 | Dibutyl phthalate               | 42.9-55.9                          | 2.5                                    | 22.36 |
|                 | Phthalic anhydride              | <0.03                              | 1                                      | <0.03 |

Note: Occupational exposure limits—styrene and dibutyl phthalate meant time-weighted average allowable concentration, Phthalic anhydride meant the highest permissible concentration; E/OEL-Ratio of Air Concentration to Occupational Contact Limit

3.3. Qualitative risk assessment results
According to the on-site occupational hygiene survey, the amount of raw and auxiliary materials used in curing agent filling, cement filling and finished product packaging posts was appropriate. The chemical volatility of styrene and phthalic anhydride was moderate, and dibutyl phthalate was low; the above substances were not dustproof. The hazard grade of styrene was B, and that of dibutyl phthalate and phthalic anhydride was D. Converting the risk level to the risk ratio level, the risk level of chemical harmful factors involved in each position was the same. The risk grade of styrene was 2, dibutyl phthalate was 3 and phthalic anhydride was 4. The results were shown in Table 2.

Table 2. Qualitative Risk Assessment of Occupational Health in an Anchorage Workshop.

| Positions       | Occupational Hazardous Factors | Usage   | Volatility | Contact Level | Hazard Ranking | Risk Level | Risk Ratio Level |
|-----------------|---------------------------------|---------|------------|---------------|---------------|------------|------------------|
| Curing Agent    |                                 |         |            |               |               |            |                  |
| Bottling        | Styrene                         | Moderate| medium     | 3             | B             | 2          | 2                |
|                 | Dibutyl phthalate               | Moderate| low        | 2             | D             | 3          | 3                |
|                 | Phthalic anhydride              | Moderate| medium     | 3             | D             | 4          | 4                |
| Cement Filler   |                                 |         |            |               |               |            |                  |
|                 | Styrene                         | Moderate| medium     | 3             | B             | 2          | 2                |
|                 | Dibutyl phthalate               | Moderate| low        | 2             | D             | 3          | 3                |
|                 | Phthalic anhydride              | Moderate| medium     | 3             | D             | 4          | 4                |
| Product Packing |                                 |         |            |               |               |            |                  |
|                 | Styrene                         | Moderate| medium     | 3             | B             | 2          | 2                |
|                 | Dibutyl phthalate               | Moderate| low        | 2             | D             | 3          | 3                |
|                 | Phthalic anhydride              | Moderate| medium     | 3             | D             | 4          | 4                |

3.4. Risk Assessment Result of Contact Limit Ratio Method
According to E/OEL judgment, the contact grade of chemical harmful factors involved in each post was the same, among which the contact grade of styrene was 2, the contact grade of dibutyl phthalate was 5, and the contact grade of phthalic anhydride was 1. In terms of hazard grade, the hazard grade of styrene was 3, and that of dibutyl phthalate and phthalic anhydride was 2. Calculate the risk grade and converted into the risk ratio grade. The risk grade of chemical harmful factors involved in each position was the same. The risk grade of styrene was 2, the risk grade of dibutyl phthalate was 3, and the risk grade of phthalic anhydride was 1. The results were shown in Table 3.
Table 3. Results of Contact Ratio Method in Anchorage Production Workshop.

| Positions         | Occupational Hazardous Factors | E/OEL | Contact Level | Hazard Ranking | Risk Level | Risk Ratio Level |
|-------------------|--------------------------------|-------|---------------|---------------|------------|-----------------|
| Curing Agent Bottling | Styrene                        | 0.37  | 2             | 3             | 2          | 2               |
|                   | Dibutyl phthalate               | 21.28 | 5             | 2             | 3          | 3               |
|                   | Phthalic anhydride              | <0.03 | 1             | 2             | 1          | 1               |
| Cement Filler     | Styrene                        | 0.33  | 2             | 3             | 2          | 2               |
|                   | Dibutyl phthalate               | 22.00 | 5             | 2             | 3          | 3               |
|                   | Phthalic anhydride              | <0.03 | 1             | 2             | 1          | 1               |
| Product Packing   | Styrene                        | 0.27  | 2             | 3             | 2          | 2               |
|                   | Dibutyl phthalate               | 22.36 | 5             | 2             | 3          | 3               |
|                   | Phthalic anhydride              | <0.03 | 1             | 2             | 1          | 1               |

3.5. Risk Assessment Result of Comprehensive Index Method

The determination of hazard level was the same as that of contact ratio method. The hazard grade of styrene was 3, and that of dibutyl phthalate and phthalic anhydride was 2. On the basis of comprehensive consideration of occupational health management, hazard control measures, daily use of chemical substances, daily contact time and other factors, the contact grade was determined. The contact grade of chemical harmful factors involved in each post was the same. The contact grade of styrene was 3, the contact grade of dibutyl phthalate was 3, and the contact grade of phthalic anhydride was 2. The calculated risk grade was converted to risk ratio grade. The calculated results of risk grade of chemical harmful factors involved in each position were the same. The risk grade of styrene was 3, the risk grade of dibutyl phthalate was 2, and the risk grade of phthalic anhydride was 2.

Table 4. Results of Comprehensive Index Method in Anchorage Production Workshop.

| Positions         | Occupational Hazardous Factors | Contact Level | Hazard Ranking | Risk Level | Risk Ratio Level |
|-------------------|--------------------------------|---------------|---------------|------------|-----------------|
| Curing Agent Bottling | Styrene                        | 3             | 3             | 3          | 3               |
|                   | Dibutyl phthalate               | 3             | 2             | 2          | 2               |
|                   | Phthalic anhydride              | 2             | 2             | 2          | 2               |
| Cement Filler     | Styrene                        | 3             | 3             | 3          | 3               |
|                   | Dibutyl phthalate               | 3             | 2             | 2          | 2               |
|                   | Phthalic anhydride              | 2             | 2             | 2          | 2               |
| Product Packing   | Styrene                        | 3             | 3             | 3          | 3               |
|                   | Dibutyl phthalate               | 3             | 2             | 2          | 2               |
|                   | Phthalic anhydride              | 2             | 2             | 2          | 2               |

3.6. Summary of results of risk assessment methods

Qualitative risk assessment, contact ratio method and comprehensive index method were used to assess the risk of the resin anchorage agent workshop. The risk levels of chemical harmful factors involved in different positions were the same. For the evaluation of styrene, the results of qualitative risk assessment and contact ratio method were consistent, while the results of comprehensive index method were slightly higher; The results of qualitative risk assessment and contact ratio method for dibutyl phthalate were consistent, while the results of comprehensive index method were slightly lower; For phthalic anhydride, the evaluation results of the three methods were different, the qualitative risk assessment results were the highest, and the contact ratio method was the lowest. Generally speaking, the results of qualitative risk assessment and contact ratio method were similar or the same. The results were shown in table 5.
Table 5. Evaluation Results of Three Risk Assessment Methods.

| Positions          | Occupational Hazardous Factors | Qualitative Risk Assessment | Contact Ratio Method | Comprehensive Index Method |
|-------------------|--------------------------------|----------------------------|----------------------|----------------------------|
| Curing Agent Bottling | Styrene                        | 2                          | 2                    | 3                          |
|                    | Dibutyl phthalate              | 3                          | 3                    | 2                          |
|                    | Phthalic anhydride             | 4                          | 1                    | 2                          |
| Cement Filler     | Styrene                        | 2                          | 2                    | 3                          |
|                    | Dibutyl phthalate              | 3                          | 3                    | 2                          |
|                    | Phthalic anhydride             | 4                          | 1                    | 2                          |
| Product Packing   | Styrene                        | 2                          | 2                    | 3                          |
|                    | Dibutyl phthalate              | 3                          | 3                    | 2                          |
|                    | Phthalic anhydride             | 4                          | 1                    | 2                          |

4. Discuss

Occupational health risk assessment can provide scientific basis and guidance for risk management for employers, and formulate specific preventive measures and emergency measures based on the results of risk assessment. So as to achieve the goal of preventing occupational hazards and implementing the control of occupational hazards [8]. In recent years, many domestic scholars have applied different risk assessment models to assess occupational hazards [9-11], enriched the theory and practice, and provided a basis for employers to formulate health risk control strategies.

Qualitative Risk Assessment (QRIA) is used to determine the exposure level, which mainly considers the physical characteristics and usage of chemicals. It is more suitable for the situation of harmful factors without occupational exposure limits or the lack of access to relevant information such as test data. However, due to the less restrictive conditions and lack of data support, the evaluation results was easily to lead to the lack of objectivity [12].

The application of semi-quantitative risk assessment-comprehensive index method involves vapor pressure or aerodynamic diameter of chemical substances, chemical usage, exposure time of workers and occupational hazards control measures of employers, etc. The factors considered are comprehensive and practical. Semi-quantitative risk assessment-exposure limit ratio method to determine the exposure level only depends on the ratio of air concentration to occupational exposure limit, which seems to be too simple to consider. However, the essence of the comprehensive index method and the contact limit ratio method are the same, and there should be no great difference in the evaluation results between the two methods in theory [13]. However, qualitative and semi-quantitative risk assessment methods are only applicable to chemical substances and dust [14].

The summary results of three different risk assessment methods showed that the qualitative risk assessment and the contact ratio method were more similar than the comprehensive index method, but the results of the two methods were quite different for phthalic anhydride. According to on-site occupational hygiene survey and occupational hygiene test results, the actual test results of phthalic anhydride samples were lower than the detection limit of equipment, far below the occupational hygiene limit, which indicating that the substance had less actual harm in anchorage agent production workshop. Based on the above analysis, we considered the semi-quantitative risk assessment-contact limit ratio method as more practical for anchorage agent workshop.

In this paper, styrene, dibutyl phthalate and phthalic anhydride were identified as the chemical harmful factors to be evaluated, mostly due to the substances have not only national standard detection methods, but also occupational health limits, which can be more scientific and objective to determine the degree of hazards. Because of the low content of other ingredients in the raw materials of resin anchorage agent, or because of the lack of standard detection methods and occupational health limits, qualitative risk assessment methods could be the only choice to select. The lack of data support may lead to the poor objectivity of the results of occupational health risk assessment.
The results of this practice showed that different assessment models had the same risk rating of chemical harmful factors involved in different positions. By on-site occupational hygiene survey, because although the types of work/positions were different, they belong to the upstream and downstream relationship in technology, the processes were connected, and chemical agents were no longer added in the production process, together with the proximity of the job sites, the occupational hazards of each job were the same and there were mutual influences.

Under current production conditions, the curing agent filling, cement filling and product packaging posts in the resin anchoring agent workshop were at medium risk level, while the styrene was at low risk level. The detection concentration of dibutyl phthalate samples exceeded the national occupational exposure limit. The workshop has not been tested for occupational hazards before. The types and degrees of occupational hazards in production sites were not clear, and there were omissions in occupational hazards prevention and control. On the basis of this study, the employer should improve the occupational hazard protection facilities on the job site, provide qualified personal occupational disease protection equipment for workers, carry out occupational health examination every year, and strengthen the management of raw and auxiliary materials, so as to minimize the level of occupational exposure and control occupational hazards from the source.

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